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ABSTRACT

Written to complement the Fluid Power/Basic Hydraulic and Basic Pneumatics guides, this curriculum guide contains materials for a seven-unit course in fluid power systems maintenance and operation. Units, which consist of one to eight lessons, cover these topics: preventive maintenance, repair machine malfunctions, overhaul/recondition hydraulic equipment, fluid sampling, test equipment, service equipment, and current system trends. Each lesson may contain some or all of the following: scope of unit; lesson objectives; supplementary learning/teaching items; student informational assignment; references (instructor's additional information); introduction; outline of key points; interaction (review) items; classroom, laboratory, shop, or other activities; evaluation items; answers to evaluation items; and transparency masters. Both information and demonstration lessons are provided. (YLB)

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ED248372

Instructor's Guide

FLUID POWER SYSTEMS MAINTENANCE AND OPERATION

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FOREWORD

The industrial vocational instructors of today face the challenge of helping students acquire skills and knowledge necessitated by a growing and changing industry. Because the competition and skill requirements for jobs are greater than ever, students in industrial vocational programs must receive the best education possible to actively compete effectively in today's market.

This guide, Fluid Power Systems Maintenance and Operation, has been written to compliment the Fluid Power/Basic Hydraulics and Basic Pneumatics guides . The instructor should refer to these two guides for basic definitions and equipment explanations as required.

An effort has been made to present demonstration lessons that give the students hands-on training on some hydraulic units and components. However, the demonstration lessons presented are neither comprehensive nor universally available in every school. Therefore, instructors, depending on the teaching laboratory resources that they have, are encouraged to modify and/or add demonstration lessons whenever it is deemed necessary and helpful.

An advisory committee composed of various industrial vocational instructors, representatives from community colleges, representatives from industry, and state department personnel were instrumental in the developing and writing of this Fluid Power Systems Maintenance and Operation curriculum guide.

ACKNOWLEDGMENTS

Appreciation is expressed to the many individual who gave their time, knowledge, and talents to the development of these materials. Without their cooperation this packet would not have been made possible.

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FLUID POWER SYSTEMS MAINTENANCE AND OPERATION

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FLUID POWER SYSTEMS MAINTENANCE AND OPERATION

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	2. Shock and Vibration
	3. How to Prevent and Check for Aeration and Cavitation
4. Aeration and Cavitation	
	5. Thermal Characteristics of Hydraulic Systems
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	6. Pressure and Flow Measurement
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OVERHAUL/RECONDITION HYDRAULIC EQUIPMENT

14. Proper Repair Procedures

15. Remove, Disassemble, Assemble, and Reinstall Hydraulic Components

16. Checking Tolerance on Parts

17. Qualify Parts for Reuse

18. Disassemble, Inspect, and Reassemble a Directional Control Valve

19. Disassemble, Inspect, and Reassemble a Pressure Compensated Variable Volume Pump

20. Test Components After Reassembly

21. Documentation of Overhaul

FLUID SAMPLING

22. Why, When, and How to Take a Fluid Sample for Testing

23. Oil Performance Specifications

24. Performing a Patch Test

TEST EQUIPMENT

25. Pressure Gages

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28. Flow Meters

SERVICE EQUIPMENT

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CURRENT SYSTEM TRENDS

30. Energy Requirements and Savings for Hydraulic Pumps

31. Module Valve Assemblies and Cartridge Valves

32. Proportional Valves

33. Introduction to Programmable Controls

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

Scope of the Unit: After completion of this unit, the student should recognize the importance of cleanliness in the reliable operation of a hydraulic system, the effects of shock, vibration, aeration, cavitation, and heat, and should be able to describe ways to reduce these factors.

LESSON 1: CHECK SYSTEM CLEANLINESS

Lesson Objectives - the student should be able to:

1. State why signs, tags, labels, etc. must be kept clean.
2. Give reasons why the area around the hydraulic equipment should be free of any obstructions.
3. Give reasons for immediate clean-up of oil spills.
4. List reasons why fluid line leakage must be repaired immediately.
5. List problems caused by cross-contamination.
6. Recall causes of leakage at static joints.
7. Describe the correct type of tube fitting to be used on hydraulic systems.
8. List reasons why airborne particles cause system damage.
9. Recall why breather caps are used on vented reservoirs.
10. State the most important rule to obey when filling a hydraulic system.
11. List precautions to follow when filling a reservoir.

Supplementary Learning/Teaching Items:

Informational Assignment: (Student)

Fundamentals of Service, Hydraulics. Moline, IL: Deere and Company, 1979, Chapter II, General Maintenance.

References: (Instructor's Additional Information)

Fundamentals of Service, Hydraulics. Moline, IL: Deere and Company, 1979, Chapter II, General Maintenance.

Introduction: The dictionary defines the word maintenance as a "means of support," and this is just what maintenance department personnel do. They "support" the company in keeping its equipment in operation so a product can be produced or a service rendered.

Maintenance can be separated into two main categories: 1) repair of broken, worn, or malfunctioning equipment and 2) preventive maintenance. Preventive maintenance is vital as it can often eliminate the need for repair.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 1: CHECK SYSTEM CLEANLINESS

Outline: (Key Points)

I. Signs and tags - the tags should be free from dirt, oil, and accumulated debris so operating personnel are aware of correct procedures.

   A. Operational signs

   B. Safety warning signs

II. Obstructions around equipment - the area around the equipment should be free of any obstructions to:

   A. Prevent personal accidents

   B. Offer a safe and rapid path of evacuation for personnel in case of an accident

   C. Offer a safe work station for both equipment operators and maintenance personnel

   D. Provide free flow of air to aid in cooling equipment

   E. Prevent equipment damage due to objects being pushed or falling into equipment

   F. Make it easy to check equipment

III. Oil spillage - oil spills around equipment should be cleaned up immediately to:

   A. Prevent personal accidents

   B. Offer a safe and rapid path of evacuation for personnel in case of an accident

   C. Offer a safe work station for both equipment operators and maintenance personnel

   D. Eliminate fire and health hazards resulting from oil spillage

   Note: It should be stressed that all oil spillage should be cleaned up and waste be disposed of by methods in accordance with local, state, and federal regulations. In many cases the least expensive method for cleaning up an oil spill is to spread a commercially available clay type material to absorb the spill. Under no condition should fluid be disposed of by flushing into sewers.

IV. Fluid line leakage - should be repaired at once because it:

A. Represents a safety hazard as discussed in Section III of this outline.

B. Is expensive - when fluid line leakage exists, the loss must be made up for by periodic refilling of the oil reservoir. Not only is there an expense for the oil but also the labor required to refill the reservoir, and the down time on the machine.

Any time a reservoir is opened to the atmosphere a condition exists that allows airborne or refilling equipment contamination to enter the hydraulic system. This can cause future problems such as excessive wear or machine malfunctions.

The cost of the oil from fluid line leakage is shown in Table 1. This table is based on a drop of oil being approximately 11/64 of an inch in diameter; a drum is equal to 55 gallons at a cost of $4.00 per gallon.

TABLE ONE: LOSSES DUE TO OIL LEAKAGE

Leak Rate	Loss in 24 Hours		Loss in One Month		Loss in One Year	
	Gallons	Dollars	Gallons	Dollars	Barrels	Dollars
One Drop Per Minute	.017	.07	.517	2.07	.113	24.86
One Drop in 10 Seconds	.099	.40	3.01	12.04	.65	143.00
One Drop in 5 Seconds	.199	.80	6.05	24.20	1.32	290.40
One Drop Per Second	.994	3.98	30.23	120.92	6.60	1452.00
Oil Stream Breaks into Drops	21.2	84.80	644.8	2579.20	140.7	30,954.00

This table is based on a drop of oil being approximately 11/64 of an inch in diameter. A drum is equal to 55 gallons at a cost of $4.00 per gallon.

V. Problems caused by cross-contamination - depending on the type of equipment, oil leakage from the hydraulic system can:

A. Contaminate other oils in the system. Oil leakage into machine cutting oils can break down the cutting oil, resulting in shortened tool life.

B. Constitute a health problem to persons ingesting a contaminated food product, if the system is part of a food process line.

C. Contaminate parts being produced, forcing a clean-up operation to be added to the manufacturing cycle.

D. Attract dust to parts being manufactured so the possibility of error exists in gaging or inspection.

E. Reduce hose and seal compatibility.

VI. Causes and prevention of leakage at static joints

A. Use of unsuitable or inferior connectors at joints

B. Lack of care in choosing or preparing connectors for assembly

C. Lack of care in making the assembly. For example, improper torquing of joints, misapplication of dope with tapered joints (Don't use Teflon tape.)

D. Faulty installation such that connection is loosened by excessive mechanical vibration or unneccessary strain

E. System connections subjected to high shock loads

F. Several preventive measures can reduce problems from the above causes.

1. Keep the number of joints to the minimum number required. This is the most important factor; without a joint there can be no leakage.

2. Adopt a consistent method to install and maintain static joints - one that has proven satisfactory in the past.

3. Train maintenance personnel in correct procedures.

4. Plan installation of joints so that the static joint is under no mechanical strain (load).

5. See that piping (tube or hose) is well supported to prevent loosening or breakage of joints by vibration.

6. Study hydraulic system to reduce or eliminate system shock, fluid surges, and pressure spikes.

VII. Reasons for using tube, causes of tube fitting leakage, and correct type of fitting

A. Tubing is preferred over pipe in a hydraulic system because, when properly installed, there is less chance of system leakage. By bending tubing, oil lines can be routed along the system without the use of connections at corners. This reduces the number of joints or potential leak passages, and gives infinite bend angle.

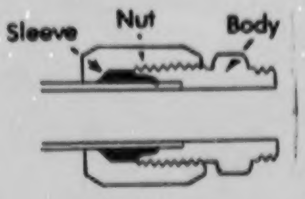
B. Tubing must be of correct size to accommodate the pressure and flow. The correct size of tubing is discussed in Unit II, Lesson 3. The normally recommended tubing is annealed, cold-drawn seamless steel tubing, type SAE 1010.

C. Tube to tube fittings

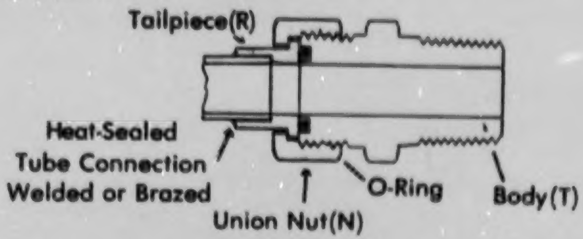
1. Use of a bite-type flareless fitting is recommended because of its excellent sealing characteristics and ease of

assembly. A bite-type fitting has a locking sleeve which, when assembled, first forms a primary seal between the tube, nut, and body. When tightened, a secondary seal is formed by the sleeve "biting" into the tube.

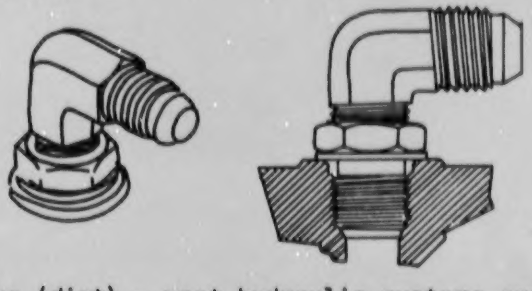
2. 37° flare fitting is commonly used, but requires pre-flaring.



D. Causes of leakage at threaded (screwed) connections - leakage at threaded connections is generally caused by improper assembly of the joint. A common threaded connector is the tapered pipe thread. Even with the use of pipe sealant, leakage can occur. The preferred method is to use SAE straight thread fitting with O-ring seal.



These fittings provide an improved method of sealing. Threaded joint fittings are available that can be rotated to the desired angle for tube alignment and tightened to produce a leak-free joint. This is not the case with tapered thread joints, where it is necessary to overtighten the connection to produce the correct alignment.



VIII. Airborne particles (dirt) - most hydraulic systems are covered with a slight oil film due to system leakage, routine maintenance, filling, etc. This film acts as a bonding agent for airborne solid particles to accumulate on the system. Dust and dirt buildup must be removed from the system by cleaning.

A. Dirt buildup on reservoirs and piping - The reservoir and piping on a hydraulic system are not only used to store and transmit fluid but to act as a cooling surface to lower the fluid temperature of the system. Dirt buildup on the reservoir and piping acts an an insulation blanket to hold heat in the system, preventing heat transfer to the surrounding air.

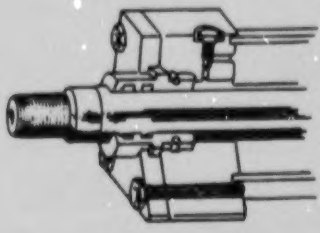
B. Airborne particles can cause clogging of cooling fins on an oil-to-air heat exchanger. One possible remedy to this problem is the fitting of filters in the air stream to remove contaminants before they reach the cooling fins of the exchanger.

C. Rotating shafts on:

1. Electric motors - dirt buildup on the rotating shaft of electric motors can migrate into the bearings, causing premature failure.

2. Gear boxes - dirt buildup on input and output shafts can damage seals, shafts, and bearings. Sometimes shaft wear can be reduced by fitting sleeves to worn shafts to help seal them against the shaft seals.

3. Fluid motors - since most front shaft seals on fluid motors are there to prevent oil leakage from the motor case (oil usually under 2-5 psig pressure), any dirt introduced into this seal area can cause rapid seal deterioration. OSHA requires all rotating shafts to be shielded, so use a tight fitting guard to help prevent dirt accumulation.



D. Reciprocating rods on hydraulic cylinders cause two major problems when they come into contact with airborne particles. (It should be remembered that because cylinder rods are always "wet" with oil to lubricate the front rod bearing, dirt is attracted to these rods.)

1. Dirt that has accumulated on the cylinder rods is drawn into the rod seal and rod bushing each time the cylinder rod is retracted into the cylinder. This causes the front seal to degenerate, allowing larger particles to enter the seal and bushing areas, accelerating this wearing process.

2. Dirt that has accumulated in surface imperfections in the rod or which migrates past the rod seal and front rod bushing when the cylinder rod is retracted into the cylinder is washed off of the cylinder rod and suspended in the working fluid. As this fluid is circulated through the system on its way back to

the reservoir, it can damage each component with which it comes in contact.

Three techniques can be used to help reduce the dirt buildup on the rod.

1. Rod boot covers - covers of cloth-reinforced rubber that completely cover the rod are the best answer if they can be used. If not, a shield over the top to prevent dust from settling on the rod is the next best choice.

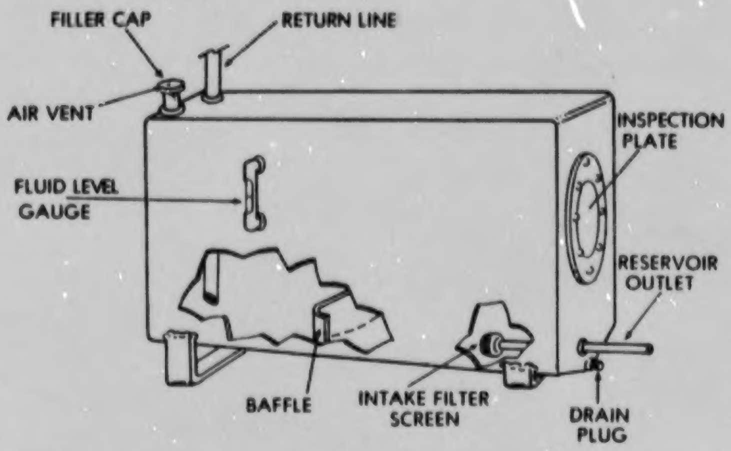
2. When possible, rods should be retracted into the cylinders if the equipment is not in use.

3. Metallic rod scrapers

In very severe environments it may be necessary to install a second set of rod wipers on the front of the rod end of the cylinder. These wipers act as sacrificial wipers to remove the major contamination before it reaches the main wiper, seal, and bushing assembly.

IX. Reservoir protection - airborne particles must be trapped before they enter the reservoir and become suspended in the fluid where, if pumped through the system, they can cause component damage.

A. Vented reservoirs - on reservoirs that are open to the atmosphere, some type of suitable filterized breather cap must be installed.



Note: Robotic systems involve rapid ingestion of ambient air.

B. These breathers must be inspected and cleaned periodically to ensure their continued operation.

X. Filling or replenishing fluid - all possible care must be taken when the working fluid is added to the reservoir so no contaminants are introduced into the system. The **most** important rule is: **No fluid is added to the system until the fluid has been filtered.**

XI. Other precautions when filling or replenishing:

A. Clean the area around the filler port of the reservoir before opening the filler port.

B. Clean tools to be used in the filling operation.

C. Have filter screen in fill port to catch any foreign bodies that could be dropped into reservoir.

D. Perhaps the best method available to fill reservoirs is through a quick-disconnect installed in the side of the reservoir. With this method, oil can be pumped out of its storage container through a bank of filters and into the reservoir without coming into contact with a source of contamination.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 1: CHECK SYSTEM CLEANLINESS

Interaction Items: (Review Items)

1. Discuss why cleanliness of a hydraulic system is so important.
2. Discuss how a good preventive maintenance program can improve the profit margin for a company (by reducing down time).
3. Discuss how proper system cleanliness can lead to longer equipment life.
4. Why do poor equipment maintenance and installation procedures lead to problems of oil leakage and early equipment failure?
5. Discuss airborne contamination and how it applies to equipment with which the student is familiar.

Classroom, Laboratory, Shop, or Other Activities:

Inspect equipment available in classroom for cleanliness and discuss findings.

LESSON 1: CHECK SYSTEM CLEANLINESS

Evaluation Items:

1. Why should signs on equipment be kept clean?

2. Obstructions around equipment should be avoided because:

   a.

   b.

   c.

   d.

   e.

3. Why should oil spills be cleaned up as soon as they occur?

   a.

   b.

   c.

   d.

4. Why should even very small fluid line leaks be repaired immediately?

   a.

   b.

   c.

5. What problems can be caused by cross-contamination of oils?

   a.

   b.

   c.

   d.

6. List five causes of leakage at static joints.

   a.

   b.

   c.

   d.

   e.

7. What type of tube fitting should be used to prevent oil leakage?

8. Airborne particles can be detrimental to a hydraulic system because:

   a.

   b.

   c.

9. Why are filterized breather caps installed on vented reservoirs?

10. What is the most important rule to observe when filling a hydraulic reservoir?

11. List three precautions that should be observed when filling a reservoir with oil.

   a.

   b.

   c.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 1: CHECK SYSTEM CLEANLINESS

Answers to Evaluation Items:

1. So operational personnel are aware of correct procedures

2. a. Prevent accidents
   b. Offer a safe escape route
   c. Offer a safe work station
   d. Free flow of air for cooling
   e. Prevent damage due to obstruction falling on equipment

3. a. Prevent accidents
   b. Offer a safe escape route
   c. Offer a safe work station
   d. Fire hazard

4. a. Safety
   b. Expensive
   c. Cross-contamination

5. a. Contamination of other oils in the system
   b. Additional labor required to clean-up parts being produced
   c. Leakage attracts dirt
   d. Health problems if oil enters food products being produced

6. a. Unsuitable connectors used
   b. Poor preparation of connectors at assembly
   c. Poor workmanship in making connection
   d. Excessive vibration
   e. Excessive shock

7. A bite type fitting that has an O-ring seal on the threaded portion of the fitting

8. a. Dirt buildup on surfaces affect cooling
   b. Clogs cooling fins on heat exchangers
   c. Abrasive action on rotating and reciprocating shafts

9. To prevent airborne contaminant from entering the reservoir

10. No fluid is added to the system until it has been filtered; even new oil is contaminated

11. a. Clean area around filler port
    b. Clean tools to be used
    c. Check to see that filter screen is in place

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

Scope of the Unit: After completion of this unit, the student should recognize the importance of cleanliness in the reliable operation of a hydraulic system, the effects of shock, vibration, aeration, cavitation, and heat, and should be able to describe ways to reduce these factors.

LESSON 2: SHOCK AND VIBRATION

Lesson Objectives - the student should be able to:

1. Recall ways of reducing shock and vibration from the prime mover.
2. Identify a way to reduce pump pulsation.
3. Describe situations when cylinders with cushions should be used.
4. Recall when a cylinder should be decompressed.
5. List two methods of reducing shock on pilot operated valves.
6. List steps that reduce shock and vibration in pipe, tubing, and hose.
7. Describe the method for removing entrapped air from a hydraulic system.

Supplementary Teaching/Learning Items:

1. TM-1 Deceleration Valve with Tapered Plunger
2. TM-2 Valve Center Conditions

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: Shock and vibration in a hydraulic system are the major causes of hose, pipe, tubing, and fitting failure, leading to early failure of hydraulic components. Pressure gages and other delicate test equipment are especially vulnerable. Shock and vibration can never be completely eliminated, but they can be reduced to a degree where they have little adverse effect on the system.

LESSON 2: SHOCK AND VIBRATION

Outline: (Key Points)

I. Prime mover - In most cases this will be an electric motor which will not contribute shock or vibration to a system if a few precautions are followed.

   A. Motor is mounted with correct size bolts.

   B. Motor base is stiff enough to resist flex and twist.

   C. Coupling is installed in accordance with manufacturer's instructions.

   D. Care is used in alignment of motor, coupling, and fluid pump.

   Note: In some cases, vibration isolation pads may be required between the motor base and its attachment point, this is especially true on internal combustion engines.

II. Fluid pump (hydraulic pump) - In most cases this component does not induce significant amount of vibration into the system if it has been properly installed in accordance with manfuacturer's instructions. One exception is when the pump has sustained internal damage, which causes it to become unbalanced.

   A. Small hydraulic shock waves can be generated by piston pumps in a system. This is called pulsation. It can be removed by the use of a small accumulator (pulsation dampener) installed in the pump outlet line.

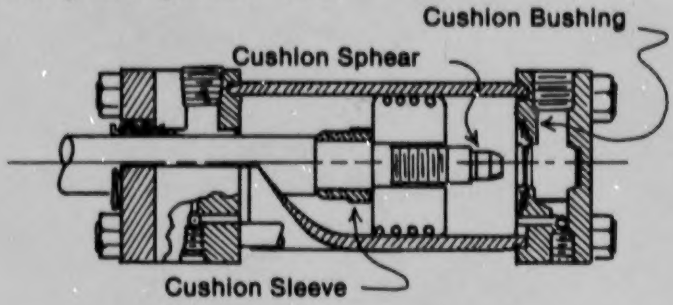
   B. To meet sound level limits and reduce vibration, the pump can be isolated from the rest of the system by using vibration mounts. This requires that all connections to the pump be made with flexible hose. This type of mounting can lead to other problems, such as early front shaft seal and bearing failure, so care should be used when considering this arrangement.

III. The cylinder as a source of system shock

   A. As the cylinder rod and piston are retracted or extended from the cylinder, they have to decelerate before they hit the head or cap end of the cylinder. This controlled deceleration can be obtained in a number of ways.

      1. Cushions: Hydraulic cylinders often have cushions installed in them to slow down the cylinder pistons at the end of travel. Cushions are tapered cones on the cylinder rod or

piston to reduce the fluid flow out of the cylinder, thus decelerating the cylinder rod.



Two types of system shock are reduced by the use of cylinder cushions.

a. Mechanical shock: Due to piston hitting the end caps at high speed.

b. Hydraulic shock: High fluid pressure spikes in the fluid line can occur between the time the cylinder piston hits an end cap and system relief valves have time to operate when cylinder piston travels at high speed.

2. Deceleration valves: If it is necessary to slow down a cylinder piston at some position other than the end of travel, an external deceleration valve can be used. These valves are usually operated by a cam mounted on the piston rod which, when it contacts the plunger of the deceleration valve, causes the valve to start restricting flow out of the cylinder. As the cam moves over the deceleration valve plunger, more fluid is restricted until the desired deceleration is achieved. (TM-1)

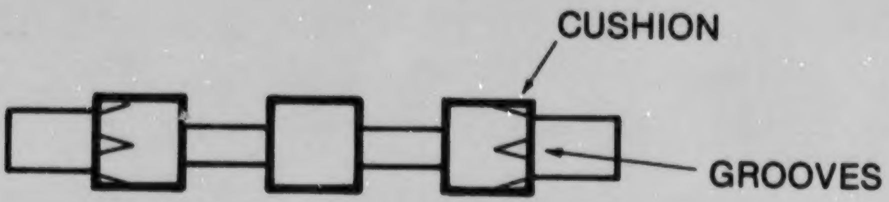
3. Limit switches: Limit switches contacted by cams mounted on the cylinder rod send an electrical signal to electromechanical valves or the pump to decelerate cylinder piston/rod as required.

IV. Decompression - On systems with large volume cylinders it may be necessary to decompress the fluid in the cylinder before return movement can occur. If decompression does not occur before directional control valves are shifted, large pressure spikes can be generated, damaging piping and valves.

V. Directional control valves

A. When the direction of fluid flow is changed or blocked too rapidly, high pressure spikes occur. To prevent this:

1. Some spool type valves have deceleration grooves cut into the spool lands to cause a gradual shift.



2. Cushions are built into spool to spool down travel speed.

B. On pilot operated directional control valves, the shifting speed of the main spool can be controlled by how fast oil is supplied to the pilot. The two most common methods are:

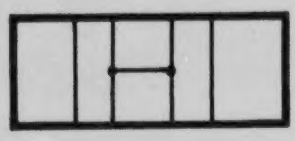
1. A needle valve is used to control the amount of oil available to shift the spool on externally piloted valves.

2. A pilot choke block can be installed between the pilot valve and the main valve. These pilot chokes control the oil coming out of the pilot section in a meter-out flow control setup. These can be used on both internally and externally piloted valves.

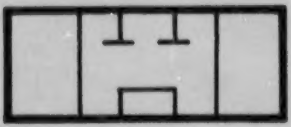
By controlling the shifting speed of the main spool, system shock can be lowered to acceptable levels.

The type of spool used in spool valves can sometimes be changed to lessen the shock produced in a system. This is usually done when the system is designed, but if severe shock is a problem, changing types of spools may help. Caution: Determine if changing spools will affect how the circuit will operate. (TM-2)

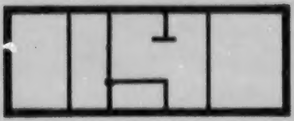
a. Open center spools produce the least amount of system shock.



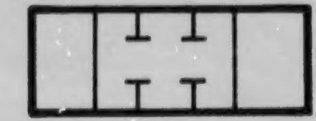
b. Tandem center spools are almost shock free if a slow spool shift speed is used and A and B ports do not have flow to a moving load.



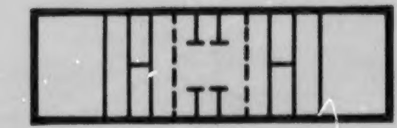
c. Float center spools do not produce shock at the A and B ports but the P port could produce some shock if spool shift speeds are rapid.



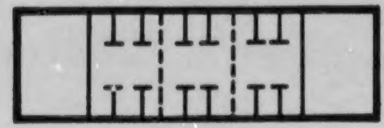
d. Closed center spools tend to generate some system shock. Under rapid spool shift, severe shock waves will always be produced.



It should be noted that there are two variations on this type of spool.



1) During shifting, ports A, B, P, and T are connected to the T port so the shock produced with this spool will be less than the spool shown in 2.



2) During shift, A, B, P, and T ports are blocked. This spool will produce very high peak pressure and severe system shock.

VI. Pipe, tube, and hose

A. Vibration and shock are most noticeable in the fluid lines of a system. Vibration, shock, and noise are amplified and can cause severe damage to the fluid lines if steps are not taken to reduce their levels.

1. Use a minimum number of fittings and connectors to reduce change in line size and direction of flow.
2. Use a minimum number of bends, with bend radius as large as possible.
3. Support all lines with vibration damping mounts to absorb both shock and vibration. Note: higher viscosity fluids attenuate shock.
4. Keep fluid line size as large as possible to reduce velocity of flow.
5. Use manifolds instead of individual lines wherever possible.
6. Use correct mounting of tubing and hose as shown in Fluid Power/Basic Hydraulics, Unit II, Lesson 3.

B. Use of accumulators to reduce shock: Accumulators can be located in the high pressure lines of a hydraulic system to reduce shock produced by rapid changes in pressure or flow rates by absorbing them. To some extent hoses also act as accumulators as they flex and swell under increasing pressure.

Accumulators will reduce the shock in the system but they do not eliminate the cause of the shock.

VII. Air

A. Air becomes trapped in a system when the system is built or during a repair. This air can cause noise and vibration as it passes through the system or when it undergoes a change in volume due to system pressure changes.

B. To solve this problem:

1. Bleed all systems at their high points before returning unit to service.
2. Let system operate at low pressure levels at first to flush out trapped air.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 2: SHOCK AND VIBRATION

Interaction Items: (Review Items)

1. Discuss uses of different center configurations on directional control valves.
2. Discuss shock and vibration and how they lead to early equipment failure.
3. Discuss shock and vibration on equipment with which students are familiar.

Classroom, Laboratory, Shop, or Other Activities:

1. Demonstrate shock on a cylinder with and without cushions.
2. Inspect lab equipment for shock and vibration.

Evaluation Items:

1. List ways of reducing shock and vibration from the prime mover.

   a.

   b.

   c.

   d.

2. Pulsation from the pump can be reduced by installing what in the pressure line?

3. When should cylinders with cushions be used?

   a.

   b.

4. When should decompression on a cylinder be used?

5. List two methods of reducing shock on pilot operated directional control valves.

   a.

   b.

6. List steps that can be taken to reduce shock and vibration in pipe, tube, and hoses on a system.

   a.

   b.

   c.

   d.

   e.

   f.

7. How can entrapped air be removed from a system?

a.

b.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 2: SHOCK AND VIBRATION

Answers to Evaluation Items:

1. a. Correct bolts used in mounting
   b. Stiff motor base
   c. Correctly installed coupling
   d. Correct alignment of motor, coupling, and pump

2. Accumulator or pulsation dampener

3. a. Piston can hit end caps
   b. High cylinder piston speed

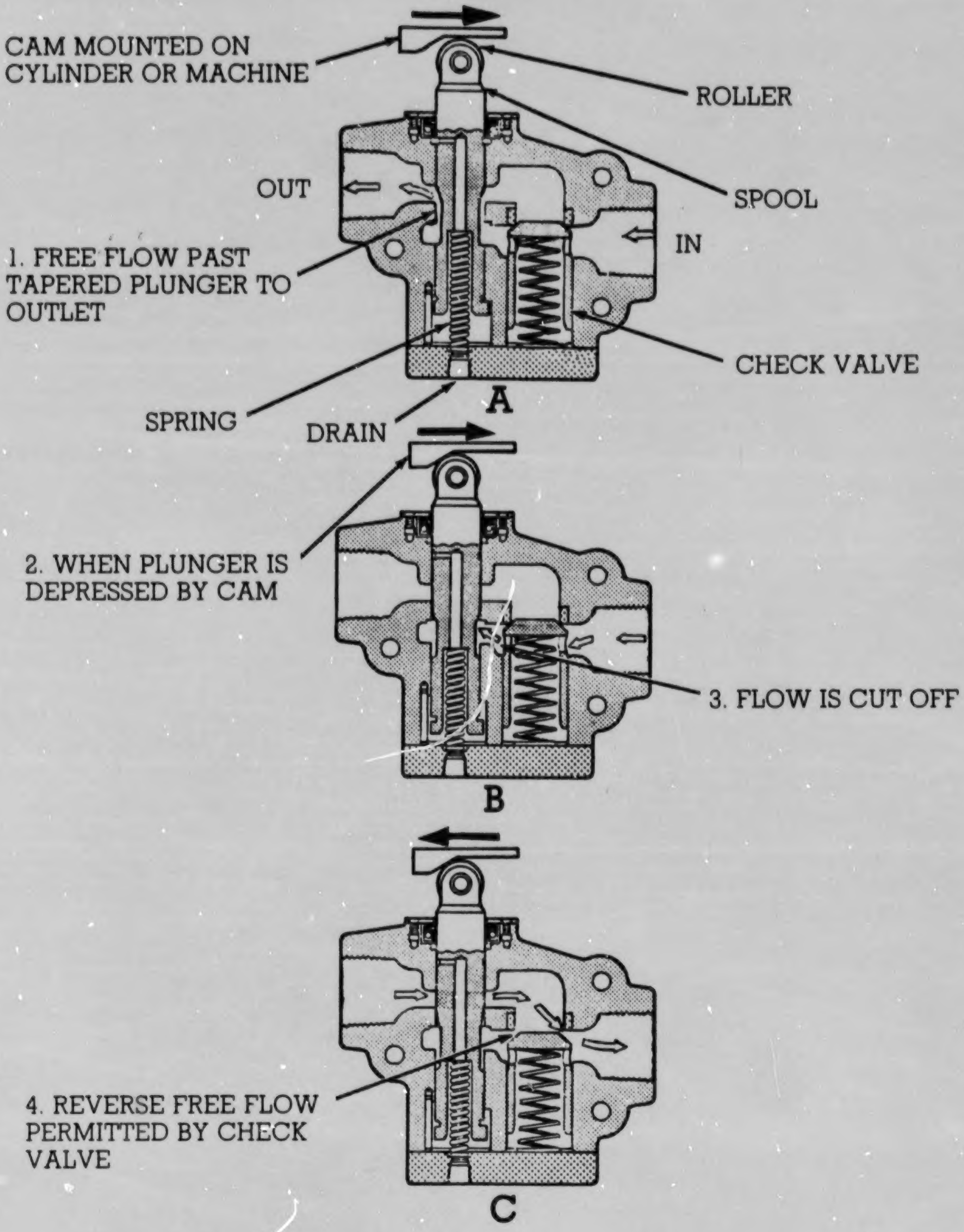
4. When cylinder has a large volume

5. a. Needle valve in oil supply line on externally supplied piloted valves
   b. Pilot shocks

6. a. Minimum number of fittings
   b. Large bends
   c. Shock/vibration damping mounts
   d. Fluid lines of largest size possible
   e. Use manifolds instead of individual lines
   f. Correct mounting methods

7. a. Bleeding at highest point(s)
   b. Operate at low pressure to circulate oil

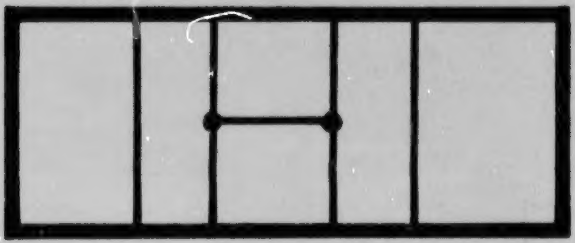
Deceleration Valve with Tapered Plunger


CAM MOUNTED ON CYLINDER OR MACHINE
ROLLER
SPOOL
OUT
IN
1. FREE FLOW PAST TAPERED PLUNGER TO OUTLET
CHECK VALVE
SPRING
DRAIN
A
2. WHEN PLUNGER IS DEPRESSED BY CAM
3. FLOW IS CUT OFF
B
4. REVERSE FREE FLOW PERMITTED BY CHECK VALVE
C

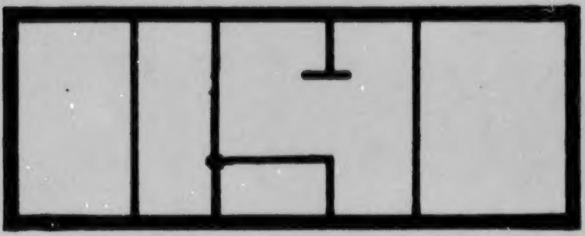
TM 2

Valve Center Conditions

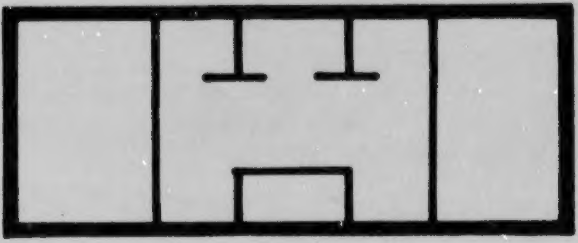
open center spool



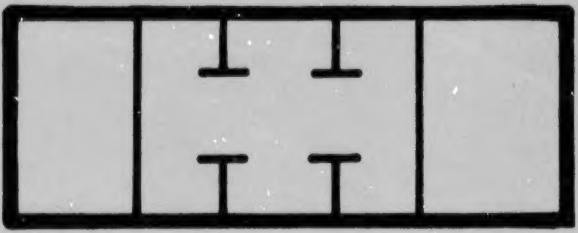
float center spool



tandem center spool

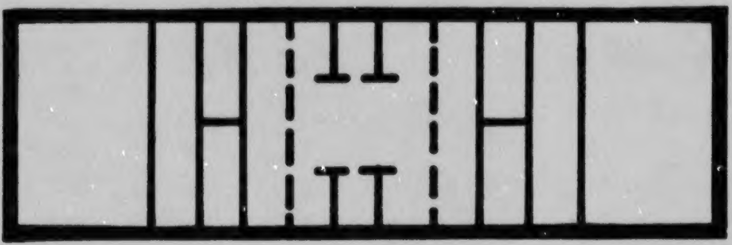


closed center spool

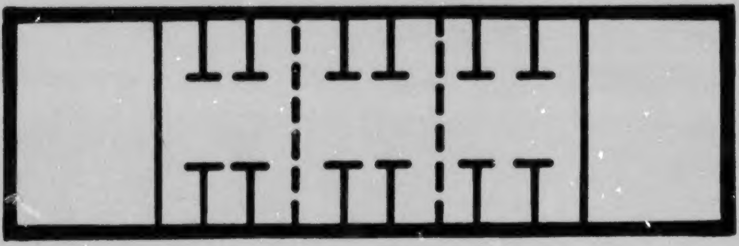


two variations
on this
type of spool

1)



2)



Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

Scope of the Unit: After completion of this unit, the student should recognize the importance of cleanliness in the reliable operation of a hydraulic system, the effects of shock, vibration, aeration, cavitation, and heat, and should be able to describe ways to reduce these factors.

LESSON 3: HOW TO PREVENT AND CHECK FOR AERATION AND CAVITATION

Lesson Objectives - the student should be able to:

1. Define aeration.
2. List problems caused by aeration.
3. Describe how to check for aeration.
4. List ways to reduce aeration.
5. Define cavitation.
6. List ways to check for cavitation.
7. List causes of cavitation.
8. List ways to prevent cavitation.
9. Recall main problem when using high-water-based fluids (HWBF).

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Industrial Hydraulic Technology. Parker Fluid Power. Chapter 3.

Introduction: Aeration or cavitation can occur in any hydraulic system. If either does occur, rapid pump failure will result.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 3: HOW TO PREVENT AND CHECK FOR AERATION AND CAVITATION

Outline: (Key Points)

I. Aeration - The introduction of air into the pump because of:

   A. Air leaks in suction line hose, pipes, and fittings. Because pump inlet pressure is less than atmospheric air pressure, air can enter the pump through suction (inlet) line leaks.

   B. Oil foaming: Air in the form of free bubbles (not dissolved) can produce oil foaming.

II. Problems caused by aeration

   A. Source of pump noise and vibration

   B. Causes of internal pump damage

   C. Air bubbles in fluid produce a compressible air cushion which can cause erratic valve and cylinder operation.

   D. Increased oxidation rate

III. Testing for aeration

   A. Check reservoir for oil foaming.

   B. Install vacuum gage in pump inlet line.

   C. Apply a coating of heavy grease to all hose and fitting connections to close off any air leaks on inlet piping. Vacuum reading will increase when air leaks are stopped.

IV. Stopping aeration

   A. All return lines into the reservoir should terminate below oil level to prevent splashing, which generates foam.

   B. Use correct materials and installation procedures to eliminate air leaks on fluid inlet lines.

   C. Maintain correct reservoir fluid levels.

   D. Use baffles (in the correct size of reservoir) which allow the oil to remain in the tank long enough for air bubbles to escape from the oil.

V. Cavitation - Liquids vaporize when subjected to a vacuum. Cavitation happens when an increase in vacuum pressure occurs in the pump inlet line. When vaporization starts to occur in the pump inlet (because of an increase in the partial vacuum required to force the oil into the pump), voids are formed in the fluid. These voids pass through the pump and implode (collapse) with considerable force when exposed to the higher positive pressure at the pump outlet. Problems that are caused by cavitation are:

A. Imploding voids cause metal fatigue and erosion inside the pump.

B. Unbalanced pump operation

C. Reversal of loading on pump parts (ex. pistons are pulled from their sockets)

D. Increase in noise and vibration

VI. Testing for cavitation

A. Install a vacuum gage in pump inlet line.

B. Compare vacuum gage reading with pump manufacturer's allowable inlet line vacuum requirements.

VII. Causes of cavitation

A. Pump mounted too high above fluid level

B. Low reservoir fluid level

C. Clogged or damaged inlet strainer or piping

D. Inlet piping too small

E. Too many bends in inlet piping or inlet line too long

F. Breather on reservoir is too small or clogged.

G. Collapsed inlet hose to pump from reservoir

H. Cold starting

I. Wrong oil

J. Improper pump application

K. Altitude/barometric pressure

VIII. Ways to prevent cavitation

A. Mount pump below fluid level to acquire supercharge effect.

B. Maintain correct fluid levels.

C. Periodically inspect and clean inlet strainer and piping.

D. All inlet piping should be in accordance with pump manufacturer's specifications. A good rule of thumb is: All inlet piping should be as large as the pump inlet port(s).

E. Use as short and direct a route as possible from the reservoir to the pump on inlet piping.

F. Periodically replace breather cap filters.

G. If hose is used on inlet piping it should be of the spiral-wound, wire-reinforced type.

H. Install heaters in reservoir to warm oil during cold weather start-ups.

I. Use an oil with a low vapor pressure point.

IX. High-water-based fluids (HWBF) - Special considerations should be given to a system which uses water-based fluids. Water has a high vapor point. Flooded or supercharged suction lines should always be considered in HWBF systems.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 3: HOW TO PREVENT AND CHECK FOR AERATION AND CAVITATION

Interaction Items: (Review Items)

1. Discuss how cavitation and aeration apply to equipment the student is familiar with.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 3: HOW TO PREVENT AND CHECK FOR AERATION AND CAVITATION

Evaluation Items:

1. What is aeration?

2. List problems caused by aeration.
   a.
   b.
   c.

3. List steps in checking for aeration.
   a.
   b.
   c.

4. List ways to reduce aeration.
   a.
   b.
   c.
   d.

5. Define cavitation.

6. List steps in checking for cavitation.
   a.
   b.

7. List causes of cavitation.
   a.
   b.
   c.

d.

e.

f.

g.

h.

i.

j.

8. List ways to prevent cavitation.

a.

b.

c.

d.

e.

f.

g.

h.

i.

9. If high-water-based fluids are used in a system, what should be done to the inlet piping?

LESSON 3: HOW TO PREVENT AND CHECK FOR AERATION AND CAVITATION

Answers to Evaluation Items:

1. The pulling of air into the pump

2. a. Noise and vibration
   b. Pump damage
   c. Erratic system operation

3. a. Inspect reservoir for foaming
   b. Install vacuum gage inlet line
   c. Apply grease and piping joints

4. a. All return lines into the reservoir should terminate below oil level to prevent splashing which generates foam
   b. Use correct materials and installation procedures to eliminate air leaks on fluid inlet lines
   c. Maintain correct reservoir fluid levels
   d. Use baffles (in the correct size of reservoir) which allow the oil to remain in the tank long enough for air bubbles to escape from the oil

5. Forming of gas bubbles in pump due to increase in vacuum pressure

6. a. Install vacuum gage inlet line
   b. Compare results with manufacturer's specifications

7. a. Pump mounted too high above fluid level.
   b. Low reservoir fluid level
   c. Clogged or damaged inlet strainer or piping
   d. Inlet piping too small
   e. Too many bends in inlet piping or too long an inlet line
   f. Clogged or too small a breather installed on reservoir
   g. Collapsed inlet hose to pump from reservoir
   h. Cold starting
   i. Wrong oil
   j. Improper pump application

8. a. Mount pump below fluid level
   b. Maintain correct fluid levels
   c. Periodically inspect and clean inlet strainer and piping
   d. All inlet piping should be in accordance with pump manufacturer's specifications
   e. Use short, direct route from pump to reservoir on inlet piping
   f. Periodically replace breather cap filters
   g. If hose is used on inlet piping, it should be spiral-wound, wire-reinforced

   h. Install heaters in reservoir to warm oil during cold weather startups
   I. Use an oil that has a good vapor pressure point

9. Flooded or supercharged

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

Scope of the Unit: After completion of this unit, the student should recognize the importance of cleanliness in the reliable operation of a hydraulic system, the effects of shock, vibration, aeration, cavitation, and heat, and should be able to describe ways to reduce these factors.

LESSON 4: AERATION AND CAVITATION (DEMONSTRATION LESSON)

Lesson Objectives - the student should be able to:

1. Recognize vacuum gage reading when a pump aerates.
2. Identify the pump sound produced by aeration.
3. Recognize vacuum gage reading when a pump cavitates.
4. Identify the pump sound produced by cavitation.
5. Practice safety precautions.

Supplementary Teaching/Learning Items:

1. TM-1 Circuit to Produce Aeration and Cavitation

Informational Assignment: (Student)

1. Review Aeration/Cavitation, Unit I, Lesson 3

References: (Instructor's Additional Information)

Introduction: Demonstrate aeration and cavitation to show how noise and vibration are produced. It is very important to listen to the sounds produced by aeration and cavitation so that they can be identified in the future.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 4: AERATION AND CAVITATION

Outline: (Key Points)

I. Demonstrate aeration - Steps of procedure to cause aeration

- A. Close valve #2.
- B. Open valve #1 and #3.
- C. Start motor/pump.
- D. Close valve #1 until a pressure of 50 - 100 psi is observed on gage #1.
- E. Record vacuum reading from gage #2.
- F. Slowly open valve #2 to allow a small amount of air to enter system.
- G. Observe air bubbles in clear tube.
- H. Record vacuum reading from gage #2.
- I. Record what is happening; look at oil.
- J. Open valve #2 to allow more air to enter system.
- K. Observe air bubbles in clear tube.
- L. Record vacuum reading from gage #2.
- M. Record what is happening; look at oil.
- N. Slowly close valve #2. Observe change in sound and vacuum gage reading.
- O. Open valve #1.
- P. Stop pump/motor.

Note: The pump should not be subjected to aeration for any extended period of time, as damage to the pump will result.

II. Demonstrate cavitation - Steps of procedure to cause cavitation

- A. Close valve #2.
- B. Open valves #1 and #3.

C. Start motor/pump.

D. Close valve #1 until a pressure of 50 - 100 psi is observed on gage #1.

E. Record vacuum reading from gage #2.

F. Slowly close valve #3 (a small amount) to produce resistance to flow.

G. Record vacuum reading from gage #2.

H. Observe change in pump sound.

I. Close valve #3 (a little more).

J. Record vacuum reading from gage #2.

K. Observe change in pump sound.

L. Close valve #3 all the way for just a second - then open.

M. Record vacuum reading from gage #2.

N. Observe change in pump sounds.

O. Open valves #1 and #3.

P. Stop pump/motor.

Note: Cavitation will cause damage to the pump so valve #3 should not be closed off for any extended period of time.

III. Have instructor check work.

A. Identification of basic components and circuit hook-up

B. Operating procedure

C. Safety precautions

LESSON 4: AERATION AND CAVITATION

Interaction Items: (Review Items)

1. Call attention to difference in sound produced by aeration and cavitation. Explain why the sounds are different.
2. Discuss safety precautions.
3. Discuss the gage readings which were recorded and determine why they were produced.
4. Discuss how a vacuum gage installed in the suction line of a pump would be a useful maintenance tool.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 4: AERATION AND CAVITATION

Evaluation Items:

The student has satisfactorily completed the following steps of procedure:

I. Recognized vacuum gage reading during aeration.

II. Explained pump sound produced by aeration.

III. Recognized vacuum gage reading during cavitation.

IV. Explained pump sound produced by cavitation.

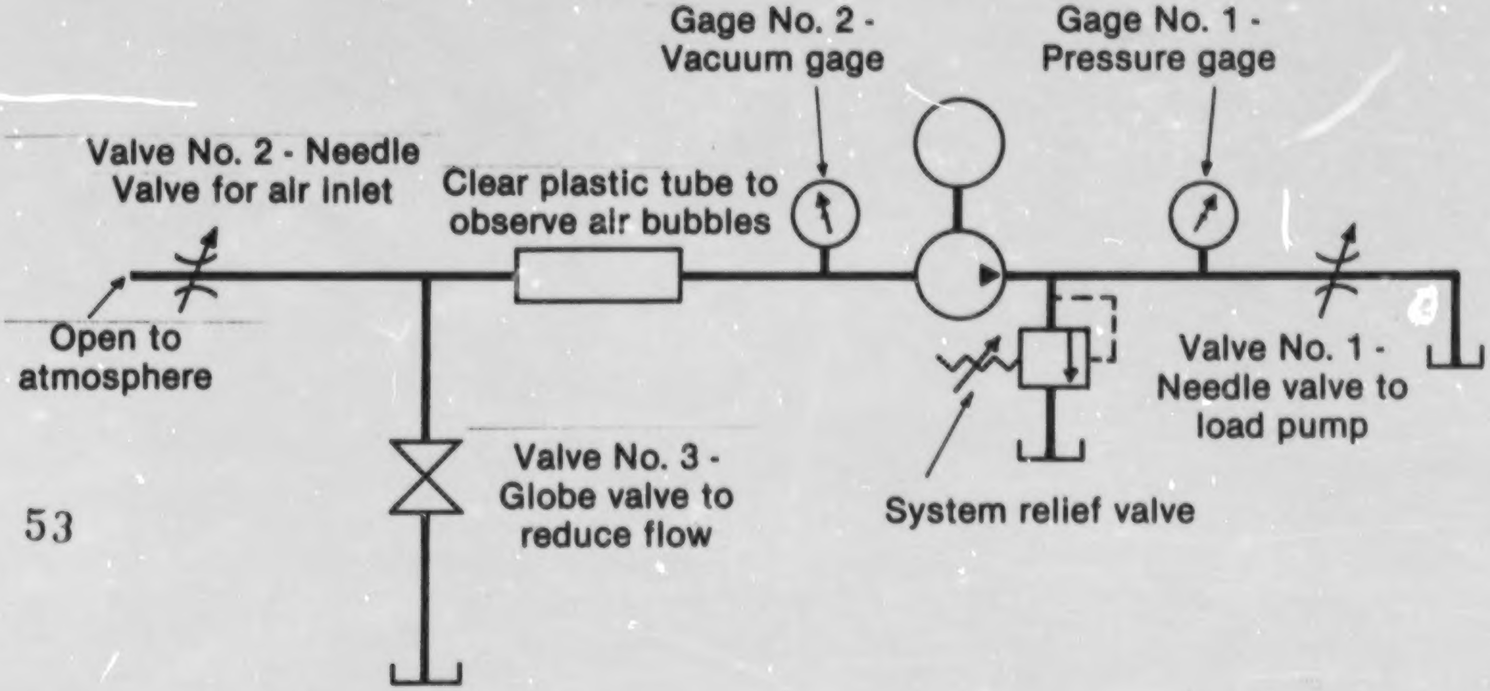
V. Practiced safety precautions while conducting this demonstration.

Yes ______ No ______

____
Instructor's Signature
(Verifying Satisfactory Completion)

Date: ______________________

Circuit to Produce Aeration and Cavitation


Gage No. 2 - Vacuum gage
Gage No. 1 - Pressure gage
Valve No. 2 - Needle Valve for air inlet
Clear plastic tube to observe air bubbles
Open to atmosphere
Valve No. 1 - Needle valve to load pump
Valve No. 3 - Globe valve to reduce flow
System relief valve

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

Scope of the Unit: After completion of this unit, the student should recognize the importance of cleanliness in the reliable operation of a hydraulic system, the effects of shock, vibration, aeration, cavitation, and heat, and should be able to describe ways to reduce these factors.

LESSON 5: THERMAL CHARACTERISTICS OF HYDRAULIC SYSTEMS

Lesson Objectives - the student should be able to:

1. Describe how heat is generated in a hydraulic system.
2. List four problems caused by excessive heat.
3. Name three ways by which heat is transferred.
4.1 List two ways in which heat is produced in components.
4.2 Explain how heat generated by a relief valve can be eliminated.
4.3 Explain why heat is produced in needle valves and flow control valves.
4.4 Describe how heat is generated in hydraulic cylinders.
5. Describe how reservoirs and piping assist in removing heat from a hydraulic system.
6. Name three types of heat exchangers.
7. List five items to check when maintaining heat removal equipment.
8. List three factors to examine when considering the need for and choice of cooling equipment.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

1. Industrial Hydraulic Technology. Parker Fluidpower, Chapter 13.

Introduction: For the correct operation and long life of a hydraulic power unit, the system temperature must be kept within reasonable limits. Stationary industrial units (open loop) should not exceed 140°F. Mobile equipment and closed loop systems' normal operating temperature will be higher but system life is sacrificed.

An increase in system temperature beyond the system's normal operating point is usually an indication that the system has gone out of adjustment or one or more parts have started to fail.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 5: THERMAL CHARACTERISTICS OF HYDRAULIC SYSTEMS

Outline: (Key Points)

I. Heat generation - Heat is produced in a hydraulic power unit when oil is passed from a high pressure point to a lower pressure without performing any work - converting fluid energy into heat energy.

II. Excessive heat problems - Excess heat generation causes the oil temperature to rise, which leads to rapid destruction of the oil by:

   A. Causing the oil to oxidize

   B. Generating impurities by speed-up of chemical reaction in the oil

   C. Lowering oil film strength (because oil viscosity is temperature dependent, heat causes loss of lubrication)

   D. Plating out of additives, causing sludge and varnish to form

III. Heat transfer - Heat is transferred by three methods.

   A. Radiation: Radiation is the process whereby heat moves from a high temperature body to a lower temperature body while the bodies are not in contact with one another.

   Example: A body's temperature will rise when it is placed in direct sunlight.

   B. Conduction: Conduction is the process whereby heat moves from a high temperature body to a lower temperature body while they are in contact with one another.

   Example: An ice cube placed on a hot plate will melt because they are in contact with one another. Heat is transferred from the hot plate into the ice. A frying pan that gets hot at the handle is another example.

   C. Convection: Convection is the transfer of heat from a body at a high temperature to a body of a lower temperature by a fluid (gas or liquid) when it comes in contact with both bodies.

   Example: Air flowing through a radiator is a good example.

   D. Heat removal: In an operating hydraulic system most of the heat that is generated will be removed from the system by:

      1. Conduction

2. Convection

IV. Heat production and reduction in system components

A. Pumps: Heat is generated in the pump:

1. As slip (leak) oil passes from the high pressure section of the pump to lower pressure sections

2. By friction between the moving parts

Heat is removed from the pump by the oil and sent back to the reservoir by:

1. Working oil passing through the pump

2. Leak oil returned via the case drain

As the pump wears, internal pump clearance increases. This allows more oil to leak through, thus generating more heat. A periodic check of pump temperature should be made by feeling:

1. Pump body

2. Drain line

See if excess quantities of heat are being produced. If so, a slip check (leak test) of the pump should be made to determine if the pump must be replaced.

B. Pressure control valves: These components (relief pressure reducing, sequence, counterbalance) are usually responsible for the generation of more heat than any other component in the system. Oil flowing across a relief valve generates heat. To prevent this from happening:

1. Use a pressure compensated pump.

2. Use an unloading valve.

3. Design the system so the relief valve functions only in an emergency.

C. Flow controls (needle valves): The flow through these valves produces heat because of pressure drop through the valves. They should only be used when absolutely necessary. It is more desirable to choose a pump with the correct flow rate than one that is larger where the flow has to be reduced by using flow control valves. Not only is heat produced by the pressure drop across the valve, but any fluid that cannot pass through the valve must be relieved by the relief valve, which will cause heat to be generated.

D. Directional control valves: These valves must be large enough to handle the desired fluid flow without excessive pressure drop (less than 100 - 150 psi if possible). Excessive pressure drops through the valve will generate excess heat.

E. Fluid motor: Fluid motors, like pumps, will produce heat when worn because of excessive slip oil.

F. Cylinder: Cylinders which have worn piston seals or rings will generate heat due to oil slipping from the high to low pressure side of the cylinder.

In general, any component that has an internal leak path will generate heat.

V. Heat removal - Since excessive oil temperatures will cause premature failure of the hydraulic components in the system, this heat must be removed. The operating components of the system do this to some extent.

A. Reservoirs: Heat can be transferred by convection from the oil to the side wall of the tank where the heat is dissipated. The top of the tank offers almost no help because it is not in contact with the oil. The bottom of the tank is not much better, in most cases, because air does not pass under freely to allow the heat to be drawn away. Because the reservoir is such a good heat sink (if properly designed) its current fluid level must be maintained to allow the oil to transfer heat to the side walls. Common practice is to have 2 - 3 times the pump delivery (in gallons) of oil in the reservoir at all times.

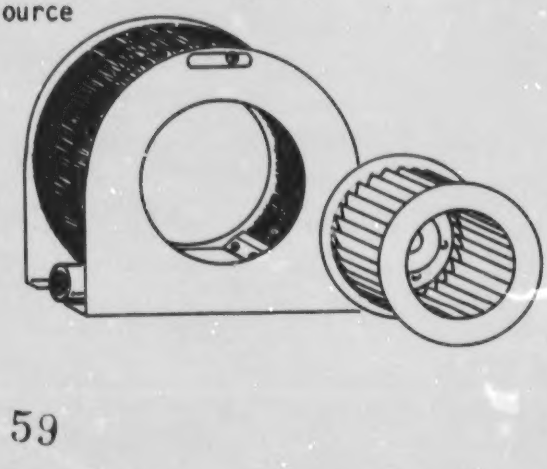
B. Piping: This part of the system will allow heat to be passed to the air if it is kept clean from external dirt buildup.

VI. Auxiliary heat removal (heat exchangers) - Some systems, because of 1) environmental conditions, 2) power requirements, or 3) poor design, will generate more heat than can be removed by the reservoir and fluid lines (piping). When this happens some type of auxiliary cooling equipment must be installed in the system. The most common types are:

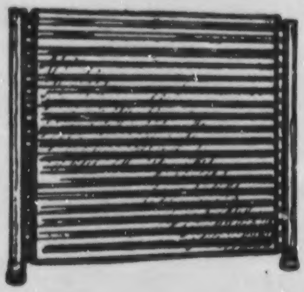
A. Air-oil coupling guard heat exchangers

This type of heat exchanger is used when a relatively small amount of flow (such as case drain oil) is to be cooled. The advantages of this type of heat exchanger are:

1. Requires no external power source
2. Serves as a coupling guard
3. Requires no water source
4. Is relatively inexpensive



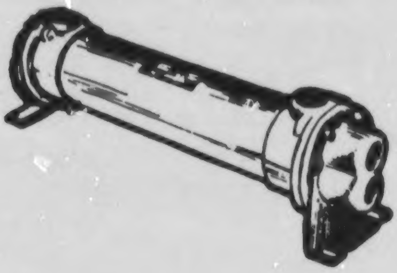
B. Air-oil (fan cooled) fin type heat exchangers



This type of heat exchanger is used to remove heat from a high oil flow system where a water source is not readily available. The advantages of this type of heat exchanger are:

1. Requires no water
2. Can be thermostatically controlled
3. Can be mounted remote from power unit

C. Water-oil (tube and shell) heat exchangers



This type of heat exchanger is used to remove large quantities of heat from a system. The advantages of this type of heat exchanger are:

1. Can remove large quantities of heat
2. Does not require cool ambient temperatures
3. Can be mounted remote from power unit

This type of unit is usually mounted with counterflow water piping.

VII. Maintenance of heat removal equipment - This equipment should be periodically checked for:

A. Cleanliness of cooling fins on types A and B

B. Water strainer cleanliness on type C

C. Mineral deposits on tubes in type C

D. Oil tube deposits and blockage on types A, B, and C

E. Cleanliness of air filter on type B

VIII. Special considerations for cooling equipment

A. Is cooling equipment required to remove heat, or could heat be eliminated by a design change?

B. Should cooling equipment be removed from system during cold weather?

C. Can heat removed from a hydraulic system be used? (For example, to heat shop air)

D. Coolers, in general, are low-pressure rated devices.

E. Water cooled heat exchangers must be drained if exposed to freezing temperatures.

LESSON 5: THERMAL CHARACTERISTICS OF HYDRAULIC SYSTEMS

Interaction Items: (Review Items)

1. Discuss thermal characteristics of equipment with which students are familiar.
2. Discuss oil cooling on automotive engines.

Classroom, Laboratory, Shop, or Other Activities:

1. Inspect shop equipment for thermal problems.

LESSON 5: THERMAL CHARACTERISTICS OF HYDRAULIC SYSTEMS

Evaluation Items:

1. How is heat generated in a hydraulic system?

2. List four problems caused by excessive heat.

   a.

   b.

   c.

   d.

3. Name three ways by which heat is transferred.

   a.

   b.

   c.

4.1 Heat is produced in pumps and other components by:

   a.

   b.

4.2 How can heat generated by a relief valve be eliminated?

   a.

   b.

   c.

4.3 How do needle valves and directional flow control valves produce heat?

4.4 When will a cylinder produce heat?

5. Describe how these components assist in removing heat from a hydraulic system.

   a. reservoir

   b. piping

6. Name three types of oil coolers.

   a.

   b.

   c.

7. List five items to check when maintaining cooling equipment.

   a.

   b.

   c.

   d.

   e.

8. List three factors to examine when considering the need for and choice of cooling equipment.

   a.

   b.

   c.

Fluid Power Systems Maintenance and Operation

Unit 1: Preventive Maintenance

LESSON 5: THERMAL CHARACTERISTICS OF HYDRAULIC SYSTEMS

Answers to Evaluation Items:

1. Oil passing from a higher to lower pressure converts fluid energy into heat

2. a. Causes oil to oxidize
   b. Generates impurities
   c. Causes loss of lubrication
   d. Forms sludge and varnish

3. a. Radiation
   b. Conduction
   c. Convection

4.1 a. Slip (or leak) oil
    b. Friction

4.2 a. Use a pressure compensated pump
    b. Use an unloading valve
    c. Redesign the system

4.3 By causing a pressure drop through the valve

4.4 When piston rings or seals have worn

5. a. Reservoir: heat can be transferred by convection from the oil to the sidewall of the tank, where the heat is dissipated.
   b. Piping: heat can be passed to the air

6. a. Air-oil coupling guard type
   b. Air-oil fan cooled type
   c. Water-oil type

7. a. Cleanliness of cooling fins
   b. Water strainer cleanliness
   c. Mineral deposits
   d. Deposits and blockage of oil tubes
   e. Cleanliness of air filters on coolers

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

Scope of Unit: After the completion of this unit, the student should be able to measure pressure and flow, and explain the process of troubleshooting. The student should be able to replace components, adjust them, check that they are operational, and complete the followup paperwork required for documentation. This knowledge will be evidenced by correctly performing the procedure outlined in the demonstration lessons and by scoring 85 percent or better on the evaluation items.

LESSON 1: PRESSURE AND FLOW MEASUREMENT

Lesson Objectives - the student should be able to:

1. Define pressure and flow.

2.1 Recognize units of measurement for pressure.

2.2 Define the purpose of a pump.

3. Describe the correct mounting position for bottom inlet and rear inlet pressure gages.

4. State the purpose of snubbers.

5. List the correct steps to install a pressure gage.

6.1 Recognize the unit of measurement for flow.

6.2 Name the two basic types of flow measurement equipment.

7. List six factors for which flow meters are calibrated.

Supplementary Learning/Teaching Items:

1. Flow and pressure gages from shop

Informational Assignment: (Student)

Read Unit VI, Lesson Plan 1: Pressure and Flow Measurement, from Basic Pneumatics

References: (Instructor's Additional Information)

Basic Pneumatics. Columbia, MO: Instructional Materials Laboratory, University of Missouri, 1983.

Introduction: For maintenance personnel to be able to diagnose the condition of a hydraulic system and its components, they must be able to accurately measure the pressure and flow at different points in the system.

LESSON 1: REPAIR MACHINE MALFUNCTIONS

Outline: (Key Points)

I. Definitions

A. Pressure: A force exerted over a surface area divided by the area of its application.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

B. Flow: The movement of a fluid from one point to another in the system.

II. Measurement of Pressure

A. Positive Pressure Measurement

1. The customary units of pressure which will be used are psig (pounds per square inch gage) which is usually stated just psi.

2. Pressure is the measure of a fluid's resistance to flow. The positive displacement hydraulic pump receives oil from the reservoir, passes it through the pump and drives it into the system.

NOTE: The pump is generating flow - not pressure.

As the system's resistance to flow increases (due to more power being required), the system pressure increases until the pump's (or system's) pressure rating is reached. When this pressure is reached, the system's main relief valve opens enough to maintain this pressure. To measure this and other pressures in a system, the maintenance personnel must be able to install the pressure gage in both the correct manner and place in the system.

B. Negative Pressure (Vacuum) Measurements

1. The customary units of pressure which will be used are - psig [negative pounds per square inch gage or (+) or (-) in. HG (positive or negative inches of mercury)].

2. Type of Equipment

a. Bourdon tube or bellows tube - almost all maintenance work involving negative pressure will be performed with this type of gage. They measure negative (-) psig or inches of mercury vacuum.

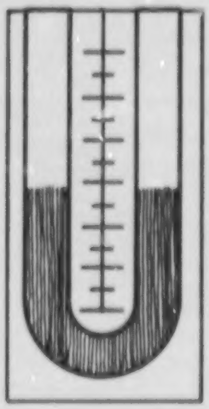
b. U-tube mercury manometer: This type of equipment is only used when very accurate data is required. In most cases it should not be used. Because it measures + or - inches of mercury.

1) The degree of accuracy is not normally required in maintenance work.

2) Equipment is large and awkward compared to bourdon tube type gages.

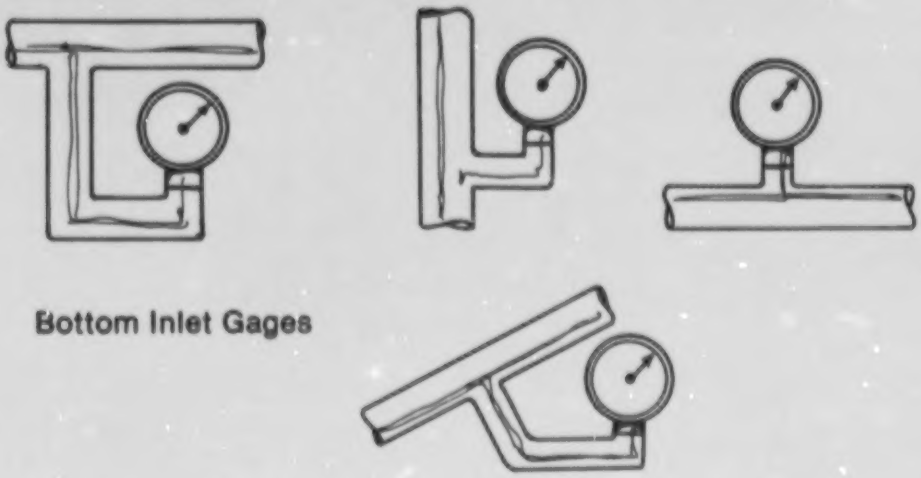
3) Manometers are more delicate and expensive than bourdon tube gages.

U-tube Mercury Manometer



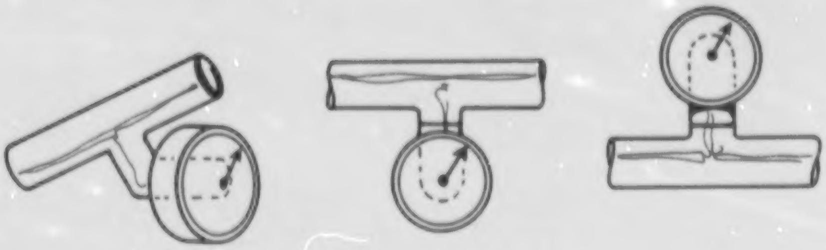
III. Installation of Positive Pressure Gages. All bourdon tube type pressure gages must be mounted in the correct relationship with the ground due to gravitational effects on the inner workings of the pressure gage.

A. Bottom inlet gages: The dial is perpendicular to the ground and the inlet is down. Any other orientation will produce an erroneous pressure reading.



Bottom Inlet Gages

B. For rear inlet gages, the dial is perpendicular to the ground with the inlet horizontal. Any other orientation will produce an erroneous pressure reading.



Rear Inlet Gages

C. Installation of negative pressure gages - The same rules for positive pressure gage installation also apply to negative pressure gages. On a positive pressure type gage any leakage due to faulty installation will be readily noticeable because the fluid has the ability to leak out of the system. This is not the case with negative pressure gages where leakage is into the system so care should be exercised when applying the thread sealant tape or dope that all leak paths are eliminated.

IV. Snubbers

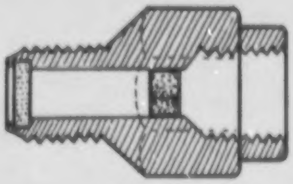
A. Definition: Devices used to restrict the rapid change in pressure between a pressure source and a pressure gage

B. Reason for use: Since vibration or shock can cause damage to the inner workings of a pressure gage and a pressure gage cannot be read accurately if the needle (pointer) is vibrating, a snubber should always be installed between the gage and the pressure point that is being measured.

C. How they work: Snubbers restrict a rapid change in pressure by reducing the size of the pressure orifice to the gage. Since there is no flow through the gage, the orifice does not represent a restriction in the line to cause a pressure drop.

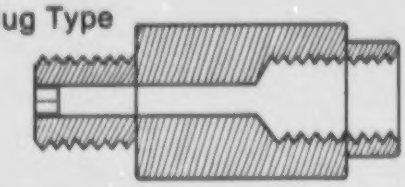
D. Basic types:

1. Porous metal: A plug of sintered bronze or stainless steel (other material types available if required) is placed in the fluid path between the gage and pressure line to absorb the shock waves.

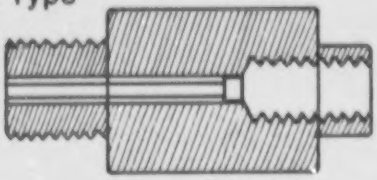


2. Restrictor type: This snubber has a passage for the oil that is many times greater in length than it is in diameter so that pressure waves are not allowed to pass through the hole.

Plug Type



Rod Type



V. Gage Installation Procedure: To install a pressure gage in a system the following procedure should be followed.

A. Check system to determine the value of the pressure to be measured and then pick a gage with a full scale reading 1 1/4 to 4 times that value. The accurate portion of a pressure gage dial is from 1/4 to 3/4 of full scale.

If the system pressure is not known, assume the maximum rating of the pump. A lower range gage can be installed later if needed.

Excessive pressure applied to the gage can distort the bourdon tube, causing erroneous readings or can burst the bourdon tube.

B. Inspect gage for damage. The needle should set on the peg. There should be no case damage, stripped threads, etc.

C. Check gage calibration sticker for last date of calibration. Gage should have been calibrated within the last year.

D. Coat threads of gage with pipe sealant and install in snubber.

Do not use the gage case to turn gage. Use only the wrench flats provided at the fluid inlet.

E. Check gage face for proper orientation as explained in section III.

F. Coat threads of snubber with pipe dope or tape and install in pressure port.

Use wrench flats on snubber, not on gage.

VI. Flow Measurements

A. The customary units of measurement are in^3/min (inches cubed per minute) or GPM (gallons per minute).

B. 1 gallon = 231 in^3. The conversion from in^3 to gallons is:

$$\text{Gallons} = \frac{in^3}{231}$$

Example: 462 in^3/min of flow is

$$\frac{\text{Gal}}{\text{Min}} = \frac{462\ in^3}{231} = 2\ \text{Gal/Min}$$

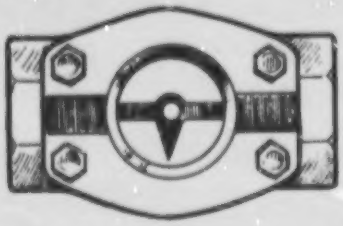
C. Types of flow measurement equipment

1. Variable Area Type

a. Vane type

1) Rugged construction

2) Accuracy ± 2%



b. Orifice type - direct reading

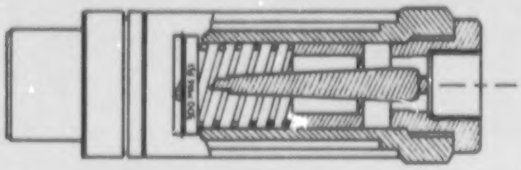
1) Low cost

2) Relatively insensitive to mounting position

3) Rugged construction

4) Accuracy ± 5%

5) High pressure measuring device



c. Rotameter

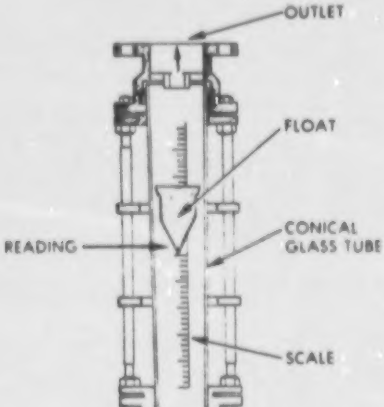
1) Usually a low pressure flow measuring device

2) Can produce very accurate measurement (± .5%)

3) Delicate in nature

4) Must be mounted in a vertical position only

5) Outlet pressure usually must be close to atmospheric pressure


OUTLET
FLOAT
CONICAL GLASS TUBE
READING
SCALE
INLET

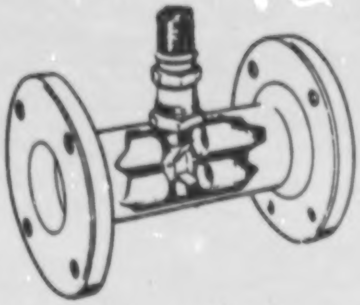
2. Turbine type

   a. Rugged construction

   b. Will accept impurities in fluid flow

   c. Accuracy ± 5%

   d. Can measure high pressure



D. Installation of Flow Measurement Devices

1. Consult specific manufacturers' catalogs for information on how devices should be mounted; each unit is different.

2. Check compatibility of flow meter pressure rating with maximum pressure rating of system.

3. Use flow gage with a range of twice the flow rate of the system if possible.

VII. Calibration of Flow Meters: All flow meters have been calibrated for:

A. A specific type of fluid

B. An operating temperature

C. A specific direction of flow

D. A specific viscosity

E. A specific pressure

F. A certain flow rate or range

The flow that is to be measured should closely match that to which the gage is calibrated.

LESSON 1: PRESSURE AND FLOW MEASUREMENT

Interaction Items: (Review Items)

1. Discuss pressure and flow measurements on equipment with which students are familiar.

2. Discuss importance of pressure and flow measurements in troubleshooting a circuit.

3. Discuss flow measurement with which students are familiar in their daily lives - electric, gas, and water billing from utility companies, purchase of gasoline for auto.

Classroom, Laboratory, Shop, or Other Activities:

1. Pass pressure and flow measuring devices around in class.

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 1: PRESSURE AND FLOW MEASUREMENT

Evaluation Items:

1. Define:

   a. Pressure

   b. Flow

2.1 Pressure is measured in what units?

   a. Positive pressure:

   b. Negative pressure:

2.2 What is the purpose of a pump?

3. Pressure gages are mounted in what position?

   a. Bottom inlet:

   b. Rear inlet:

4. What are snubbers used for?

5. List the correct steps used to install a pressure gage.

   a.

   b.

   c.

   d.

   e.

   f.

6.1 Flow is measured in what units?

6.2 Name two basic types of flow measuring equipment.

a.

b.

7. Flow meters are calibrated for:

a.

b.

c.

d.

e.

f.

Answers to Evaluation Items

1. a. A force exerted over a surface area divided by the area of application
   b. The movement of a gas or liquid from one point to another in the system

2.1 a. psi
   b. psig, or ± in. HG in HG vacuum

2.2 To produce flow, not pressure

3. a. Dial perpendicular to ground, inlet down
   b. Dial perpendicular to ground, inlet horizontal

4. To reduce shock loads on the gage

5. a. Check system for correct gage to use
   b. Inspect gage for damage
   c. Check calibration date
   d. Coat threads of gage with pipe dope and install snubber
   e. Check gage for proper orientation
   f. Coat threads of snubber with thread sealant and install in pressure port

6.1 in^3/min or gal/min

6.2 a. Variable area
   b. Turbine

7. a. Type of fluid
   b. Temperature
   c. Direction of flow
   d. Viscosity
   e. Pressure
   f. Flow rate

Unit 2: Repair Machine Malfunctions

Scope of Unit: After the completion of this unit, the student should be able to measure pressure and flow, and explain the process of troubleshooting. The student should be able to replace components, adjust them, check that they are operational, and complete the followup paperwork required for documentation. This knowledge will be evidenced by correctly performing the procedure outlined in the demonstration lessons and by scoring 85 percent or better on the evaluation items.

LESSON 2: PROCEDURE FOR TROUBLESHOOTING HYDRAULIC SYSTEMS

Lesson Objectives - the student should be able to:

1. Define troubleshooting.
2. List the seven steps required to troubleshoot a system, and explain each step.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

Fundamentals of Service, Hydraulics. Chapter 12: Diagnosis and Testing of Hydraulic Systems.

References: (Instructor's Additional Information)

Fundamentals of Service, Hydraulics. Moline, IL: Deere and Co., 1979.

Introduction: To repair a malfunction on a system or a piece of equipment it is first necessary to troubleshoot the system to determine the problem.

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 2: PROCEDURE FOR TROUBLESHOOTING HYDRAULIC SYSTEMS

Outline: (Key Points)

I. Definition of troubleshooting

   A. Troubleshooting is the process that determines what is wrong with a system. This procedure isolates and identifies the system's malfunction, its deficiencies, or the worn or broken part(s). Troubleshooting involves observing and evaluating symptoms, determining probable causes and specifying appropriate repairs. It is not concerned with replacing parts or actually fixing the machine; that is maintenance. However, in troubleshooting, components may actually be replaced and other repairs made to verify that the diagnosis was correct.

   B. Good troubleshooting is not a hit or miss guessing game or an exercise in component changing. It is a systematic approach to problem solving, which requires discipline to follow a prescribed procedure, to reach a definite conclusion without making false judgments. By using a systematic method of troubleshooting, obscure and hidden problems are less likely to be overlooked. Once the problem or problems have been determined and the appropriate fix has been prescribed, troubleshooting ends and maintenance takes over.

II. Troubleshooting involves seven fundamental steps

   A. Step 1: Know the system

      1. The troubleshooter should be familiar with the hydraulic circuit, having read all the related technical manuals on the machine, its component bulletins, and specification sheets.

      2. Be able to trace the flow through the system on the hydraulic schematic and to identify all of the components on the schematic with the actual locations on the machine.

      3. Know how and in what sequence the machine is required to operate.

      4. Know all important data, such as system operating pressure, speed of linear and/or rotary actuators, and system cycle times. Flow rates from the pump(s) to each component should be reviewed and recorded on the circuit schematic if it has not been done before.

      5. Review machine history to recall previous problems.

      6. The most important point before proceeding to step 2 is to have a copy of the electric circuit and a copy of the

hydraulic schematic to study and keep with you at all times when troubleshooting.

B. Step 2: Talk to the machine operator

1. The machine operator is most familiar with the machine on a daily basis. In most cases this machine operator reported the problem you will be troubleshooting. The operator will know who worked on the machine, preventive maintenance that has been performed and when, and what has been going wrong. The machine operator may have done something wrong and will volunteer this information to you.

2. The troubleshooter should question the machine operator on how she/he has been running the machine. It is not uncommon for production people to try to use a machine for things it was not designed to do, then complain that the machine will not work.

3. Information gathered by questioning the machine operator should be recorded.

C. Step 3: Operate the machine yourself

1. Turn the machine on and cycle the hydraulic fluid through the machine until normal operating temperature has been reached.

2. Operate the machine and try to duplicate the original complaint or malfunction.

3. Take great care in observing pressure and flow gages, speed of operation of linear and rotary actuators, reaction time of components, unusual noise, vibration, or heat, and any erratic component operation.

4. During this step, safety precautions should be followed to the letter. The troubleshooter should always be positioned at the machine operator's work station. All other personnel should be warned away from the machine. Any required protective garb such as eye shields, hard hats, safety shoes, etc. should be worn.

D. Step 4: Machine inspection

1. Before beginning the visual inspection, make sure all safety precautions have been taken. For example,

   a. On presses, block up the ram(s) or lower platen onto bed.

   b. Lower or support booms and buckets on mobile equipment.

2. Mentally walk yourself through the machine operation sequence as you trace the flow of oil through the lines from component to component. Look for anything that is not as it should be.

3. As you proceed through the system, do not skip over any part of it. It is only natural to go right for the part of the

system where the trouble is suspected but in doing so you may miss what caused the problem in the first place.

4. Assess the general condition of the equipment. Look at and feel the fluid lines for heated areas, dirt, vibration, leaks, collapsed sections, loose fittings, etc. Note the condition of cylinder rods, and record pressure, flow, and temperature readings from gages installed in the machine. Look at all seals for signs of leakage. Check mounting bolts to see if they are all in place and tight. Look at the oil level in the reservoir. Is the fluid level correct? Does the oil look OK? (No water, heavy dirt particles, signs of foaming?) If the reservoir has magnets in it, pull them to see what has been collected. Can cooling take place or have they become blocked?

5. During this inspection make written notes on anything that does not seem correct. Note any signs of abuse, poor maintenance, or incorrect operation. Not only will this list be used in the next step in the troubleshooting procedure, but to better service the machine in the future.

E. Step 5: List possible causes

1. From the observations and recorded information gathered so far, make a list of the probable causes of the failure of the machine.

2. Keep in mind while making this list that there is usually more than one reason for the problem. Examples of some possible causes of low system pressure are:

   a. An improper relief valve setting

   b. A leak

   c. Broken relief valve spring in the pilot section

   d. Leakage in a system component

   e. A worn pump, etc.

3. Remember that a problem can be caused by more than one defect. A malfunction of a relief valve, worn pump, or leakage in a system component will all cause excessive heat to be generated so oil temperature will rise.

F. Step 6: Reach a conclusion

1. From the list of probable causes compiled in Step #5, it is necessary to select those that, if verified and repaired, will put the machine back into operation. This is the most difficult step in the troubleshooting procedure.

2. As a guide in reaching a conclusion, always check and verify first those things that are the easiest to do, even though they may not seem to be the primary reason for failure. (Example: It

is much faster to replace a pressure gage if the system pressure is a little low than to test a pump for excessive wear.)

3. Once you have decided what components you are going to check, develop a plan to be carried out from one step to the next with the least amount of effort and time.

G. Step 7: Test Conclusion

1. Once a conclusion is reached, the troubleshooter must test that conclusion. The key word here is test, using appropriate equipment as required.

2. Components cost money and time to procure, so components should not be replaced just to test the conclusion. Components should be inspected, cleaned, or adjusted as required to test their reliable operation before they are replaced.

3. Many times, when the failed component is found, it may not be the end of the search. A piece of metal stuck in a valve spool will prevent it from shifting. By removing this metal chip the valve is restored to service and the machine will function correctly again. But where did the chip come from? Is a pump about to fail, is a filter ruptured, has a tube end started to chip?

4. Once all the system malfunctions have been remedied, parts replaced as necessary and adjustments made, the system should be put through its normal operating cycle a number of times to test machine performance.

H. Preventive maintenance on shutdown equipment

1. This is also a good time to make any minor adjustments or do the required preventive maintenance on the machine.

2. Maintenance personnel are already available at the machine. Production has been halted to do the required repairs.

3. It is much better to keep a machine out of service one more hour than to come back the next day and shut the machine down again to do routine maintenance.

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 2: PROCEDURE FOR TROUBLESHOOTING HYDRAULIC SYSTEMS

Interaction Items: (Review Items)

1. Discuss the troubleshooting sequence on equipment with which the student is familiar.
2. Explain why a systematic method is required to troubleshoot a system correctly.
3. Discuss how this seven step procedure can be used on other things beside hydraulic equipment.
4. Apply this method to a system in class.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 2: PROCEDURE FOR TROUBLESHOOTING HYDRAULIC SYSTEMS

Evaluation Items:

1.1 Define troubleshooting.

1.2 Troubleshooting is not concerned with:

2.1 List the seven fundamental steps involved in troubleshooting.

a.

b.

c.

d.

e.

f.

g.

2.2 a. Explain troubleshooting Step #1

1)

2)

3)

4)

5)

6)

b. Explain Step #2

1)

2)

3)

c. Explain Step #3

1)

2)

3)

4)

d. Explain Step #4

1)

2)

3)

4)

5)

e. Explain Step #5

1)

2)

3)

f. Explain Step #6

   1)

   2)

   3)

g. Explain Step #7

   1)

   2)

   3)

   4)

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 2: PROCEDURE FOR TROUBLESHOOTING HYDRAULIC SYSTEMS

Answers to Evaluation Items:

1.1 Determines what is wrong with a system

1.2 Replacing parts or actually fixing the machine

2.1
- a. Know the system
- b. Talk to machine operator
- c. Operate the machine
- d. Inspect the machine
- e. List possible causes
- f. Reach a conclusion
- g. Test conclusion

2.2
- a.
  - 1) Study the circuit, technical manuals etc.
  - 2) Trace flow on system
  - 3) Know sequence of operation
  - 4) Know data such as flow, pressure etc.
  - 5) Review machine history
  - 6) Study circuit drawings
- b.
  - 1) Ask the operator what is wrong
  - 2) Question operator on procedure
  - 3) Record operator's information
- c.
  - 1) Warm up machine
  - 2) Try to duplicate problem
  - 3) Observe what happens
  - 4) Know and observe safety precautions
- d.
  - 1) Secure equipment in safe position
  - 2) Mentally trace sequence of operation
  - 3) Do not skip around system
  - 4) Make assessment of general condition of machine
  - 5) Record observations
- e.
  - 1) List possible causes of failure
  - 2) Usually more than one reason for same problem
  - 3) Same reason can cause different problems
- f.
  - 1) Select what components to check
  - 2) Select easiest one first
  - 3) Decide on how to check components

g. 1) Test conclusion using appropriate equipment
   2) Inspect before replacing components
   3) Search for cause of failure
   4) Test for correct operation

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

Scope of Unit: After the completion of this unit, the student should be able to measure pressure and flow, and explain the process of troubleshooting. The student should be able to replace components, adjust them, check that they are operational, and complete the followup paperwork required for documentation. This knowledge will be evidenced by correctly performing the procedure outlined in the demonstration lessons and by scoring 85 percent or better on the evaluation items.

LESSON 3: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A FIXED DISPLACEMENT PUMP

Lesson Objectives - the student should be able to:

1. Arrange in order the steps required to do a pump performance test on a fixed displacement pump.

2.1 Given the necessary data, calculate the theoretical volume, volumetric efficiency, and slip oil of a pump.

2.2 Analyze pump performance data from manufacturer's catalog.

3.1 List four conditions which must be checked when a pump is tested.

3.2 Describe what must be done before a defective pump is removed from a system.

3.3 Arrange in order the steps necessary to replace a pump.

Supplementary Learning/Teaching Items:

1. TM-1 Hydraulic Circuit Tester

2. TM-2 Parker PAF 6.3 Performance Chart (page 5A of Parker catalog 2600-1)

Informational Assignment: (Student)

Review Unit II, Lessons 10 and 11 in Fluid Power/Basic Hydraulics.

References: (Instructor's Additional Information)

Fundamentals of Service, Hydraulics Moline, Il: Deere and Co., 1979. "Hydraulic Pumps" and "Diagnosis and Testing".

Fluid Power/Basic Hydraulics. Columbia, MO: Instructional Materials Laboratory, University of Missouri, 1983.

Introduction: No parts should be replaced until tests have confirmed that they need replacement. This lesson presents a method to test pump performance to determine if a pump should be replaced.

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 3: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A FIXED DISPLACEMENT PUMP

Outline: (Key Points)

I. Testing pump performance

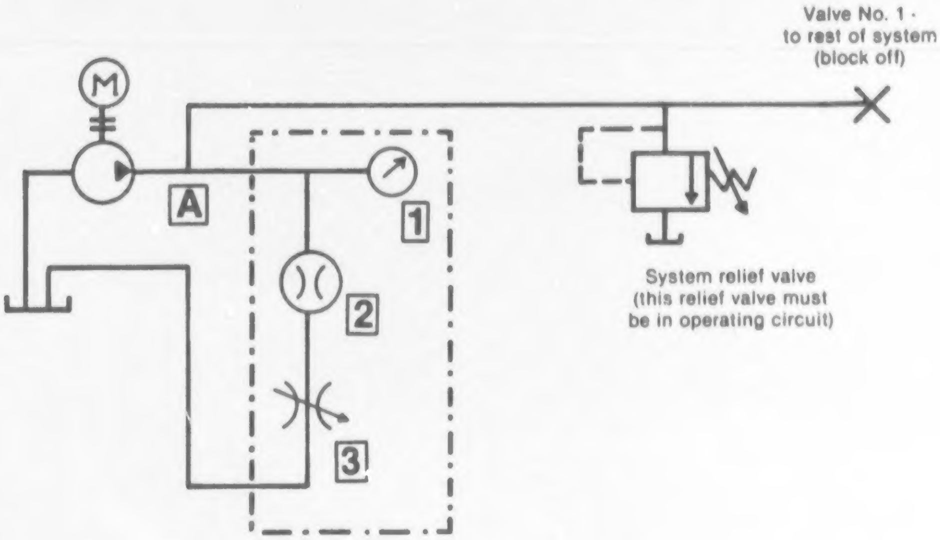
Note: Review IML Fluid Power/Basic Hydraulics (Unit II, Lesson 10).

A. Determine if a pump is operating at its required flow and is capable of delivering the flow at the required pressure. A volumetric efficiency test can be performed on the pump using a hydraulic circuit tester made from the following components:

1. pressure gage (ratio for system pressure)
2. flow meter (rated for maximum system flow and pressure)
3. needle valve (used as load valve)

Note: All of the above parts and fittings used to construct the circuit tester must be sized in conjunction with the pump's published flow and pressure rating. If the parts are too small for the flow or undersized for pressure requirements, an unsafe condition would result.

B. The above components are inserted into the hydraulic circuit as shown to test pump performance.


Valve No. 1 · to rest of system (block off)
M
A
1
2
3
System relief valve (this relief valve must be in operating circuit)

Note: Exercise care when running this type of test and making changes in any hydraulic circuit so that an unsafe situation is not created.

C. Test procedure - the test is performed as follows:

(Note: Relief valve must be operating correctly to achieve accurate test results.

1. Record motor speed _________ (Data from motor name tag or use handheld electronic tachometer)
2. Connect the hydraulic circuit tester at point A shown on TM-1.
3. Start electric motor and run system until reservoir temperature gage reads normal operating temperature.
4. Open load valve (part #3) all the way.
5. Close valve (part #1).
6. Record pressure _________ psi
   flow _________ GPM
   @ no load.
7. Close load valve until a pressure of 100 psi less than relief valve setting is reached.
8. Record pressure _________ psi
   flow _________ GPM
9. Open load valve.
10. Turn off system and disconnect hydraulic circuit tester.

II. Analyzing pump test data

A. Use the data from the test on the pump to calculate the pump's efficiency. A decision can then be made on the condition of the pump. Pump manufacturer's published data can be compared to the test data to decide if the pump is in good condition or must be replaced.

B. Steps in analyzing pump data

1. Obtain from pump manufacturer's catalog the theoretical pump displacement.
2. Find theoretical volume (flow) [Q_t] of pump from equation 1 below.

$$Q_t = \frac{\text{RPM x Displacement}}{231} \qquad (1)$$

(Note: Metric calculations may be taught.)

Where Qt = theoretical pump output in gal/min
RPM = speed of motor recorded in Step #1 of test procedure
Displacement is in^3/rev from manufacturer's catalog.

3. Calculate pump efficiency or volumetric efficiency at operating pressure from equation 2 below.

$$\% \text{ P.E.} = \frac{Q_a}{Q_t} \times 100 \qquad (2)$$

Where Q_a = actual flow in GPM measured in Step #8 of test procedure
P.E. = pump's volumetric efficiency
Q_t = theoretical flow in GPM from Step #2 of Part II. B.

4. Calculate pump slip or leak oil from the equation below.

$$Q_s = Q_{n.l.} - Q_a \qquad (3)$$

$Q_{n.l.}$ = flow at no load, measured in Step #6 of Part I. C.
Q_a = flow at load, measured in Step #8 of Part I. C.
Q_s = slip or leak oil from or in the pump

5. Compare volumetric efficiency of pump with pump volumetric efficiency curves published in the manufacturer's catalog to determine condition of the pump.

D. The above test can be performed on all types of positive displacement pumps. On mobile equipment or equipment powered by variable speed motors, this slip test should be performed at a constant speed that matches published pump data.

III. Pump replacement

A. Basis for the decision to replace pump - if the slip test shows that the pump cannot deliver the required flow at the desired pressure, repair or replacement of the existing pump is justified.

1. Before replacing the pump, check for the following conditions:

    a. Oil temperature is acceptable - high oil temperature will cause excessive slip.

    b. Correct speed - RPMs too slow will cause improper performance in some types of pumps.

    c. Correct type of oil - oil with too low a viscosity will cause excessive slip on pump at normal operational temperature.

    d. Pressure - operational pressure must be at or below manufacturer's maximum continuous pressure rating.

    e. Prime mover is operating properly.

2. If a volumetric efficiency test shows the pump is not operating at its required performance level, the pump must be removed from the system and be replaced or opened up for inspection and possible repair.

3. On very inexpensive pumps (gear pumps, especially) it is usually not worth the time or expense to tear down the pump for inspection; just replace it.

4. The cost to repair a piece of equipment is not just the expense of the parts and labor, but also the lost revenue when that piece of equipment is out of production.

B. Check the system - the following should be done prior to new pump installation:

1. Inspect oil pump for clues or reasons for pump failure.

2. Inspect system for any leaks, dirt, cleanliness problems, etc. Repair as required.

3. Take oil sample to inspect for any particles that

    a. Have damaged pump

    b. Were generated by damaged pump

4. Filter or replace oil as required.

5. Change oil filter elements.

6. Perform other preventive maintenance as required while machine is down for repair.

C. Procedure to replace pump

Note: Since there are many different types of pumps and many manufacturers of each type, the following pump replacement procedure can be used as a basic guide, but a manual for the particular pump that is being replaced should be consulted to see if any special tools or methods are utilized.

1. Obtain and review pump manufacturer's maintenance manual for proper procedure and special instructions.

2. Release any stored energy in machine (accumulators, springs, etc.), block up rams, etc., and turn off prime mover.

3. Lock-out machine power, so it cannot be started accidentally.

4. Wash (with approved solvent) the pump, all fluid lines, and fittings leading to the pump.

5. Disconnect pump inlet, outlet, and drain line(s).

6. Disconnect pump from prime mover coupling.

7. Remove pump from mounting bracket or pad.

8. Clean (with approved solvent) mounting bracket or pad.

9. Inspect mounting bracket or pad; repair or replace, if required.

10. Remount new or repaired pump, using approved fastener. Torque bolts to correct torque value in the right sequence. (Drain port, if pump has one, to top side.)

11. Check pump input shaft against prime mover shaft for correct alignment. Shim or realign as required.

12. Clean and inspect coupling. Replace if defective.

13. Install coupling.

14. Fill case drain (if pump has one) with hydraulic oil and rotate pump shaft by hand. Check for binding during rotation.

15. Connect input, output, and drain line(s) using approved fittings.

16. Restore power to machine and remove blocks as required.

17. Start-jog the pump and check 1) prime mover shaft rotation against pump shaft rotation. Arrow on pump body shows correct pump shaft rotation, and 2) noise - does the pump sound right?

18. Start-run the pump to circulate oil through the system at no load until correct operating temperature is reached.

19. Check fluid (pressure and drain) lines for leaks.

20. Check fluid inlet line(s) for air leaks.

21. Induce load on system.

22. Check for:

    a. operating speed of actuators

    b. relief valve setting

    c. general machine condition

    d. oil level

    e. oil leaks

    f. noise - does pump sound right?

LESSON 3: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A FIXED DISPLACEMENT PUMP

Interaction Items: (Review Items)

1. Review different types of fixed displacement pumps.
2. Discuss why it is important to test a pump before it is replaced and not just replace the pump because one thinks it is bad.
3. Discuss the testing of a pump with which the students are familiar.
4. Discuss why one should filter the oil when replacing a pump.
5. Discuss why the prime mover must be locked-out and any cylinders blocked up before a repair is started on a system.
6. Discuss what a pump curve would look like if speed were 1200 RPM instead of 1800 RPM. Use TM-2.
7. Discuss how to read TM-2 for input horsepower.
8. Metric units may be discussed or introduced.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 3: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A FIXED DISPLACEMENT PUMP

Evaluation Items:

1. Using TM-1, arrange in order the steps required to test a pump.

_____ a. Open load valve (part #3) all the way.

_____ b. Connect the hydraulic circuit tester at point A shown on TM-1.

_____ c. Record pressure __________ psi
flow __________ GPM
@ no load.

_____ d. Record motor speed __________ (Data from motor name tag or use handheld electronic tachometer)

_____ e. Close valve (part #1).

_____ f. Turn off system and disconnect hydraulic circuit tester.

_____ g. Close load valve until a pressure of 100 psi less than relief valve setting is reached.

_____ h. Open load valve.

_____ i. Start electric motor and run system until reservoir temperature gage reads normal operating temperature.

_____ j. Record pressure __________ psi
flow __________ GPM

2.1 Using the chart on TM-2 and the following test data

Motor speed = 1800 RPM
Actual test flow = 1.8 GPM @ 2500 psi; 2.9 GPM @ 75 psi
Actual test pressure = 2500 psi

a. What is the theoretical volume of the pump?

b. Calculate the volumetric efficiency.

c. Calculate pump slip.

2.2 Compare volumetric efficiency of test pump data to published data (use TM-2).

3.1 When a pump is tested, what conditions must be checked?

a.

b.

c.

d.

3.2 Before any pump is removed from a system, what should be done?

3.3 Arrange in order the steps necessary to replace a pump.

_____ a. Fill case drain (if pump has one) with hydraulic oil and rotate pump shaft by hand. Check for binding during rotation.

_____ b. Release any stored energy in machine, block up rams, etc., and turn off prime mover.

_____ c. Disconnect pump from prime mover coupling.

_____ d. Remount new or repaired pump, using approved fastener. Torque bolts to correct torque value in the right sequence. (Drain port, if pump has one, to top side.)

_____ e. Disconnect pump inlet, outlet, and drain line(s).

_____ f. Start-jog the pump and check 1) prime mover shaft rotation against pump shaft rotation. Arrow on pump body shows correct pump shaft rotation, and 2) noise - does the pump sound right?

_____ g. Remove pump from mounting bracket or pad.

_____ h. Clean (with approved solvent) mounting bracket or pad.

_____ i. Obtain and review pump manufacturer's maintenance manual for proper procedure and special instructions.

_____ j. Induce load on system.

_____ k. Check fluid inlet line(s) for air leaks.

_____ l. Inspect mounting bracket or pad; repair or replace, if required.

_____ m. Check pump input shaft against prime mover shaft for correct alignment. Shim or realign as required.

_____ n. Check:

1) operating speed of actuators
2) relief valve setting
3) general machine condition

4) oil level
5) oil leaks
6) noise - does all sound right?

_____ o. Clean and inspect coupling. Replace if defective.

_____ p. Restore power to machine and remove blocks as required.

_____ q. Install coupling.

_____ r. Connect input, output, and drain line(s) using approved fittings.

_____ s. Lock-out machine power, so it cannot be started accidentally.

_____ t. Check fluid (pressure and drain) lines for leaks.

_____ u. Wash (with approved solvent) the pump, all fluid lines, and fittings leading to the pump.

_____ v. Start-run the pump to circulate oil through the system at no load until correct operating temperature is reached.

LESSON 3: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A FIXED DISPLACEMENT PUMP

Answers to Evaluation Items:

1. a. Record motor speed __________ (Data from motor name tag or use handheld electronic tachometer)
   b. Connect the hydraulic circuit tester at point A shown on TM-1.
   c. Start electric motor and run system until reservoir temperature gage reads normal operating temperature.
   d. Open load valve (part #3) all the way.
   e. Close valve (part #1).
   f. Record pressure __________ psi
      flow __________ GPM
      @ no load.
   g. Close load valve until a pressure of 100 psi less than relief valve setting is reached.
   h. Record pressure __________ psi
      flow __________ GPM
   i. Open load valve.
   j. Turn off system and disconnect hydraulic circuit tester.

2.1 a. $\frac{.38(1800)}{231} = 2.96$ GPM

b. $\text{P.E.} = \frac{1.8}{2.96}(100) = 61\%$

c. $2.9 - 1.8 = 1.1$ GPM

2.2 Published data V.E. = 96%
Test data V.E. = 61%

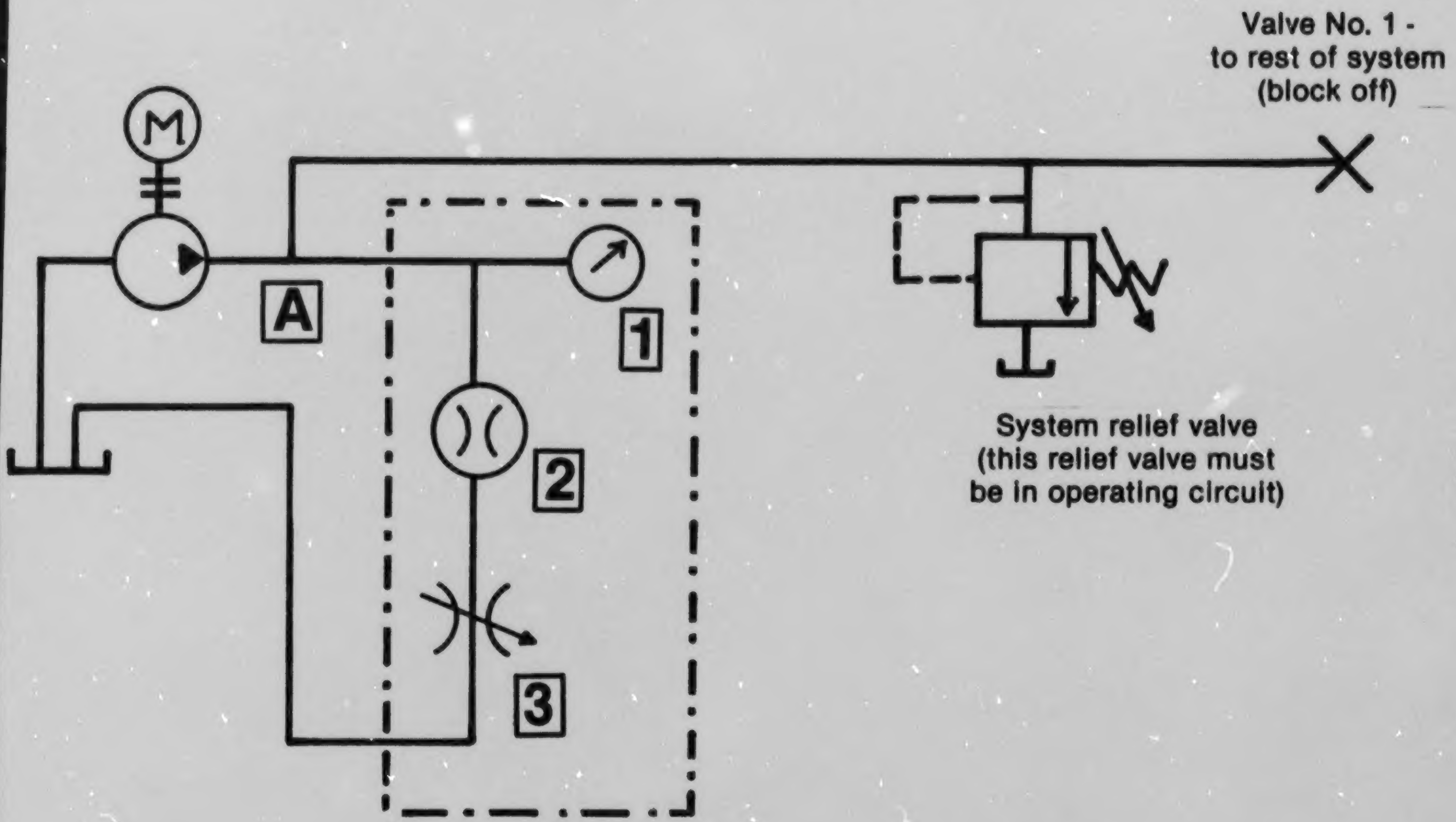
3.1 a. Oil temperature
   b. Current speed
   c. Current type of oil
   d. Current pressure range

3.2 Check manufacturer's maintenance manuals for any special instructions

3.3 a. Obtain and review pump manufacturer's maintenance manual for proper procedure and special instructions.
   b. Release any stored energy in machine, block up rams, etc., and turn off prime mover.
   c. Lock-out machine power, so it cannot be started accidentally.
   d. Wash (with approved solvent) the pump, all fluid lines, and fittings leading to the pump.
   e. Disconnect pump inlet, outlet, and drain line(s).

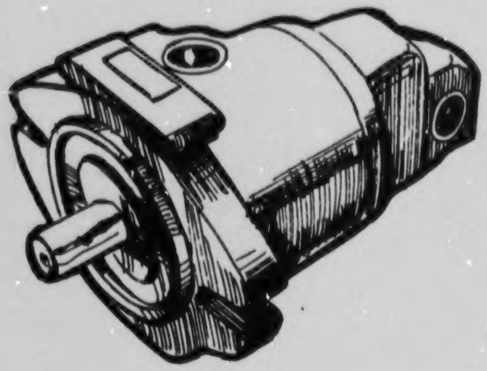
f. Disconnect pump from prime mover coupling.
g. Remove pump from mounting bracket or pad.
h. Clean (with approved solvent) mounting bracket or pad.
i. Inspect mounting bracket or pad; repair or replace, if required.
j. Remount new or repaired pump, using approved fastener. Torque bolts to correct torque value in the right sequence. (Drain port, if pump has one, to top side.)
k. Check pump input shaft against prime mover shaft for correct alignment. Shim or realign as required.
l. Clean and inspect coupling. Replace if defective.
m. Install coupling.
n. Fill case drain (if pump has one) with hydraulic oil and rotate pump shaft by hand. Check for binding during rotation.
o. Connect input, output, and drain line(s) using approved fittings.
p. Restore power to machine and remove blocks as required.
q. Start-jog the pump and check 1) prime mover shaft rotation against pump shaft rotation. Arrow on pump body shows correct pump shaft rotation, and 2) noise - does the pump sound right?
r. Start-run the pump to circulate oil through the system at no load until correct operating temperature is reached.
s. Check fluid (pressure and drain) lines for leaks.
t. Check fluid inlet line(s) for air leaks.
u. Induce load on system.
v. Check:
    1) operating speed of actuators
    2) relief valve setting
    3) general machine condition
    4) oil level
    5) oil leaks
    6) noise - does pump sound right?

Hydraulic Circuit Tester


Valve No. 1 -
to rest of system
(block off)
M
A
1
2
3
System relief valve
(this relief valve must
be in operating circuit)

Parker PAF 6.3 Pump Performance Chart

ENGINEERING PERFORMANCE DATA



SPEED
Minimum 100 RPM
Maximum 2500 RPM

PRESSURE
5000 PSI (350 Bar) Intermittent
4500 PSI (315 Bar) Continuous

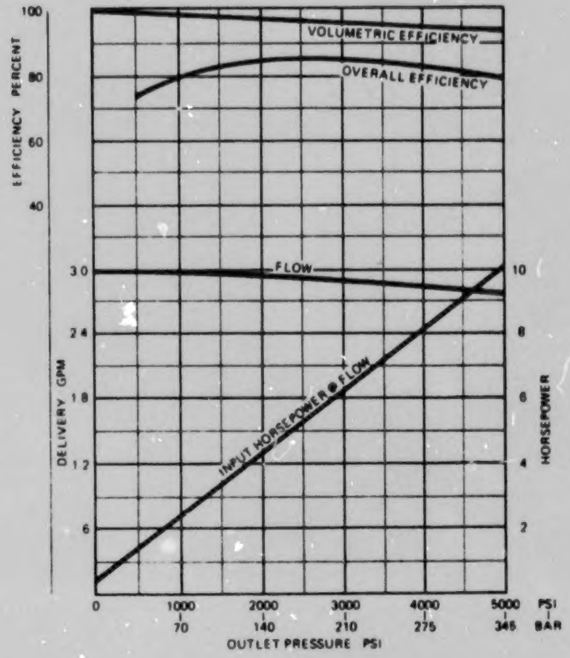
MAXIMUM FLOW
PAF 6.3 4.13 GPM (15.64 L/M)

QUICK REFERENCE DATA CHART

MODEL NUMBER	THEORETICAL DISPLACEMENT IN^3/REV. (CC/REV.)	DELIVERY GPM AT 100 PSI		*APPROX. NOISE LEVEL db(A) @ FULL FLOW 1800 RPM (1200 RPM)				APPROXIMATE HORSEPOWER AT MAXIMUM PSI & 1800 RPM
		1200 RPM	1800 RPM	500 PSI	1500 PSI	2000 PSI	4500 PSI	
PAF 6.3	.38 (6.3)	2.0	3.0	67.5 (64.5)	70.5 (68.5)	72 (68.5)	74.5 (72)	10.2

*Since many variables such as mounting, tank style, plant layout, etc., effect noise levels, it cannot be assumed that the above readings will be equal to those in the field. The above values are for guidance in selecting the proper pump. The values indicated are "Free Field" sound pressure levels at a distance of three feet from the pump. The values are based on reverberatory room measurements.

BASED ON OIL TEMPERATURE OF 120° F (100 SSU)
1800 RPM - ATMOSPHERIC INLET



NOTE:
The efficiencies and data in the graph are good for pumps running at 1800 RPM on 100 SSU viscosity hydraulic oil. To calculate the approximate required driving horsepower for other conditions, use the following formula and chart:

$$HP = \left[\frac{\text{Actual GPM} \times (\text{PSI})}{1714}\right] + CF$$

Actual GPM is proportional to drive speed for fixed pumps. Energy absorption of the pump is effected by speed and viscosity, but primarily by flow losses which are a function of pressure for normal stabilized operation. Therefore, the correction factors are based on pressure.

CORRECTION CHART

(PSI)	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
CF	.30	.50	.70	.85	1.0	1.3	1.6	1.8	2.1	2.4

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

Scope of Unit: After the completion of this unit, the student should be able to measure pressure and flow, and explain the process of troubleshooting. The student should be able to replace components, adjust them, check that they are operational, and complete the followup paperwork required for documentation. This knowledge will be evidenced by correctly performing the procedure outlined in the demonstration lessons and by scoring 85 percent or better on the evaluation items.

LESSON 4: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A VARIABLE VOLUME PRESSURE COMPENSATED PUMP

Lesson Objectives - the student should be able to:

1. Explain the difference between fixed and variable volume pressure compensated pumps.

2. Arrange in order the steps to test a pressure compensated pump.

3.1 Given the necesary data, calculate pump efficiency and slip oil.

3.2 Compare the volumetric efficiency of a test pump with published data for that pump.

4. Arrange in order the steps to replace a pressure compensated pump.

5. Arrange in order the steps to set a maximum volume stop.

6. List the steps of procedure for setting a pressure compensator.

7. Arrange in order the steps to set a minimum volume stop.

Supplementary Teaching/Learning Items:

1. TM-1 Hydraulic Circuit Tester (TM-1 from Unit 2, Lesson 3)

2. TM-2 Cut-away of Pressure Compensated Pump

3. TM-3 Parker PAV 10 Performance Chart

Informational Assignment: (Student)

Review Unit II, Lessons 10 and 11 in Fluid Power/Basic Hydraulics, Instructional Materials Laboratory.

References: (Instructor's Additional Information)

Introduction: No parts should be replaced until tests have confirmed that they need replacement. This lesson presents a method to test pump performance to determine if a pump should be replaced.

LESSON 4: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A VARIABLE VOLUME PRESSURE COMPENSATED PUMP

Outline: (Key Points)

I. Differences between fixed and variable volume pumps - pressure compensated variable volume pumps differ from fixed displacement pumps in that they can be:

   A. Pressure compensated to lower volume output, thus lowering input power requirements and heat generation at system overload and stalls

   B. Can have minimum volume adjustments

   C. Can have maximum volume adjustments

II. Testing a variable volume pressure compensated pump

   A. Since this type of pump has one or more adjustments which can affect pressure and flow, performance testing is different than for a fixed volume pump. The test equipment used to check pump performance is:

      1. Hydraulic circuit testing (TM-1)

      2. Either:

         a. Ammeter - rated for maximum current draw if electric motor is used, or

         b. Tachometer - if internal combustion engine is used to set engine speed

   B. Test procedure to determine pump condition

      1. Record motor speed __________ (Data from motor name tag or use handheld electronic tachometer)

      2. Connect the hydraulic circuit tester at point A shown on TM-1.

      3. Start electric motor and run system until reservoir temperature gage reads normal operating temperature.

      4. Open load valve (part #3) all the way.

      5. Close valve (part #1).

6. Record pressure __________ psi
flow __________ GPM
@ no load.

7. Close load valve until a pressure of 100 psi less than compensated pressure is reached. (Refer to lesson on setting pressure compensated pump.)

8. Record pressure __________ psi
flow __________ GPM

9. Open load valve

10. Turn off system and disconnect hydraulic circuit tester.

Note: For best results this test should be performed when the maximum volume stop is at a maximum flow setting.

III. Analyzing pump test data

A. Steps in procedure:

1. Calculate pump efficiency (volumetric efficiency) at operating pressure from equation #1.

$$P.E. = \frac{Q_{H.P.}}{Q_{L.P.}} \times 100 \qquad (1)$$

$Q_{H.P.}$ = flow high pressure measured in Step #8 of Part II
$Q_{L.P.}$ = flow low pressure measured in Step #6 of Part II
P.E. = pump's volumetric efficiency

2. Calculate pump slip oil from equation #2.

$$Q_s = Q_{L.P.} - Q_{H.P.} \qquad (2)$$

Q_s = leak or slip oil
$Q_{L.P.}$ = flow low pressure measured in Step #6 of Part II
$Q_{H.P.}$ = flow high pressure measured in Step #8 of Part II

3. Compare volumetric efficiency of pump with pump volumetric efficiency curves published in the manufacturer's catalog to determine the condition of the pump.

B. The above test can be performed on all types of variable displacement pressure compensated pumps without minimum and maximum volume stops, but best results are obtained when maximum volume stop is set at its maximum setting.

IV. Pump replacement

A. Basis for the decision to replace - if the slip test shows that the pump cannot deliver the required flow at the desired pressure, repair or replacement of the existing pump is justified.

1. Before replacing the pump, check for the following conditions:

    a. Oil temperature is acceptable - high oil temperature will cause excessive slip.

    b. Correct speed - RPMs too slow will cause improper performance in some types of pumps.

    c. Correct type of oil - oil with too low a viscosity will cause excessive slip on pump at normal operational temperature.

    d. Pressure - operational pressure must be at or below manufacturer's maximum continuous pressure rating.

    e. Prime mover is operating properly.

2. If a volumetric efficiency test shows the pump is not operating at its required performance level, the pump must be removed from the system and be replaced or opened up for inspection and possible repair.

3. On very inexpensive pumps (gear pumps, especially), it is usually not worth the time or expense to tear down the pump for inspection; just replace it.

4. The cost to repair a piece of equipment is not just the expense of the parts and labor, but also the lost revenue when that piece of equipment is out of production.

B. Procedure to replace pump

1. Obtain and review pump manufacturer's maintenance manual for proper procedure and special instructions.

2. Release any stored energy in machine, block up rams, etc., and turn off prime mover.

3. Lock-out machine power, so it cannot be started accidentally.

4. Wash (with approved solvent) the pump, all fluid lines, and fittings leading to the pump.

5. Disconnect pump inlet, outlet, drain, and control line(s).

6. Disconnect pump from prime mover coupling.

7. Remove pump from mounting bracket or pad.

8. Clean (with approved solvent) mounting bracket or pad.

9. Inspect mounting bracket or pad; repair or replace, if required.

10. Remount new or repaired pump, using approved fastener. Torque bolts to correct torque value in the right sequence. (Drain port, if pump has one, to top side.)

11. Check pump input shaft against prime mover shaft for correct alignment. Shim or realign as required.

12. Clean and inspect coupling. Replace if defective.

13. Install coupling.

14. Fill case drain (if pump has one) with hydraulic oil and rotate pump shaft by hand. Check for binding during rotation.

15. Connect pump inlet, outlet, and drain and control lines.

16. Restore power to machine and remove blocks as required.

17. Start-jog the pump and check 1) prime mover shaft rotation against pump shaft rotation. Arrow on pump body shows correct pump shaft rotation, and 2) noise - does the pump sound right?

18. Start-run the pump to circulate oil through the system at no load until correct operating temperature is reached.

19. Check fluid (pressure and drain) lines for leaks.

20 Check fluid inlet line(s) for air leaks.

21. Check maximum volume stop setting and adjust if necessary.

22. Check compensator setting and adjust if necessary.

23. Check minimum volume stop setting and adjust if necessary.

24. Induce load on system.

25. Check:

    a. operating speed of actuators

    b. relief valve setting

    c. general machine condition

    d. oil level

    e. oil leaks

    f. noise - does all sound right?

V. Procedure for setting maximum volume stop

A. Connect hydraulic circuit tester as shown on TM-1.

B. Start pump/motor and run system until reservoir temperature gage reads normal operating temperature.

C. Open load valve (part #3) all the way.

D. Close valve (part #1).

E. Close load valve (part #3) until a pressure of 300 psi is obtained (compensator is set higher than 300 psi).

F. Loosen maximum volume screw locknut.

G. Adjust screw (usually clockwise for decreased flow) to obtain desired setting.

H. Tighten maximum volume screw lock nut.

I. Cycle system to check setting.

J. Stop pump/motor.

K. Disconnect hydraulic circuit tester.

VI. Procedure for setting pressure compensator

A. Set compensator for maximum pressure (usually screwed in all the way).

B. Set system relief to relieve at lowest possible setting (usually screwed out almost all the way).

C. Start pump/motor and run system until reservoir temperature gage reads normal operating temperature.

D. Induce a load on the pump to produce pressure or use load valve on hydraulic circuit tester if it is on system at this time.

E. Set system relief valve 150 to 200 psi higher than compensator setting (Use system pressure gage or hydraulic circuit tester to observe pressure).

F. Set compensator to desired value.

G. Tighten locknuts on compensator and relief valve.

H. Cycle system to check operation of compensator. An ammeter can be installed across electric motor input leads to show pump compensation.

I. Stop pump/motor.

VII. Procedure for setting minimum volume stop

A. Steps in procedure

1. Place ammeter across electric motor input leads.
2. Connect hydraulic circuit tester as shown on TM-1.
3. Start pump/motor and run system until reservoir temperature gage reads normal operating temperature.
4. Open load valve (part #3) all the way.
5. Close valve (part #1).
6. Close load valve (part #1) until ammeter shows pump has compensated.
7. Loosen minimum volume screw locknut.
8. Adjust screw (usually clockwise to increase flow) to obtain desired setting.
9. Tighten minimum volume screw locknut.
10. Cycle system to check setting.
11. Stop pump/motor.
12. Disconnect ammeter and hydraulic circuit tester.

B. Check system.

1. Inspect oil pump for clues as to reasons for pump failure.
2. Inspect system for any leaks, dirt, cleanliness problems, etc. Repair if required.
3. Take oil sample to inspect for any particles that
    a. Have damaged pump
    b. Were generated by damaged pump
4. Filter or replace oil as required.
5. Perform other preventive maintenance as required while machine is down for repair.

LESSON 4: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A VARIABLE VOLUME PRESSURE COMPENSATED PUMP

Interaction Items: (Review Items)

1. Discuss the test of a variable volume pump with which the students are familiar.
2. Show students how to read TM-3.
3. On TM-3 point out differences in horsepower requirements at full flow and compensated.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 4: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A VARIABLE VOLUME PRESSURE COMPENSATED PUMP

Evaluation Items:

1. What is the difference between a fixed and a variable volume pressure compensated pump?

   a.

   b.

   c.

2. Using TM-1, arrange in order the steps required to test a pressure compensated pump.

   _____ a. Record pressure __________ psi
   flow __________ GPM
   @ no load.

   _____ b. Open load valve (part #3) all the way.

   _____ c. Open load valve.

   _____ d. Start electric motor and run system until reservoir temperature gage reads normal operating temperature.

   _____ e. Turn off system and disconnect hydraulic circuit tester.

   _____ f. Close load valve until a pressure of 100 psi less than compensated pressure is reached.

   _____ g. Record motor speed __________ (Data from motor name tag or use handheld electronic tachometer)

   _____ h. Close valve (part #1).

   _____ i. Connect the hydraulic circuit tester at point A shown on TM-1.

   _____ j. Record pressure __________ psi
   flow __________ GPM

3.1 Given the following data:

Speed = 1200 RPM
Pump = Parker PAV 10
Flow at 100 psi = 4.8 GPM
Flow at 3000 psi = 3.75 GPM

a. What is the pump efficiency?

b. What is the slip oil of the pump?

3.2 Compare volumetric efficiency of pump in the problem above with published data (use TM-3).

4. Arrange in order the steps necessary to replace a pressure compensated pump.

   a. Check pump input shaft against prime mover shaft for correct alignment. Shim or realign as required.

   b. Wash (with approved solvent) the pump, all fluid lines, and fittings leading to the pump.

   c. Connect pump inlet, outlet, and drain and control lines.

   d. Disconnect pump inlet, outlet, drain, and control lines.

   e. Lock-out machine power, so it cannot be started accidentally.

   f. Disconnect pump from prime mover coupling.

   g. Inspect mounting bracket or pad; repair or replace, if required.

   h. Remove pump from mounting bracket or pad.

   i. Clean (with approved solvent) mounting bracket or pad.

   j. Obtain and review pump manufacturer's maintenance manual for proper procedure and special instructions.

   k. Release any stored energy in machine, block up rams, etc., and turn off prime mover.

   l. Remount new or repaired pump, using approved fastener. Torque bolts to correct torque value in the right sequence. (Drain port, if pump has one, to top side.)

   m. Clean and inspect coupling. Replace if defective.

   n. Start-run the pump to circulate oil through the system at no load until correct operating temperature is reached.

o. Check fluid (pressure and drain) lines for leaks.

p. Fill case drain (if pump has one) with hydraulic oil and rotate pump shaft by hand. Check for binding during rotation.

q. Induce load on system.

r. Install coupling.

s. Check for:

   1. operating speed of actuators
   2. relief valve setting
   3. general machine condition
   4. oil level
   5. oil leaks
   6. noise - does all sound right?

t. Restore power to machine and remove blocks as required.

u. Start-jog the pump and check 1) prime mover shaft rotation against pump shaft rotation. Arrow on pump body shows correct pump shaft rotation, and 2) noise - does the pump sound right?

v. Check fluid inlet line(s) for air leaks.

w. Check maximum volume stop setting and adjust if necessary.

x. Check compensator setting and adjust if necessary.

y. Check minimum volume stop setting and adjust if necessary.

5. Arrange in order the steps necessary to set a maximum volume stop.

   a. Adjust screw (usually clockwise for decreased flow) to obtain desired setting.

   b. Open load valve (part #3) all the way.

   c. Tighten maximum volume screw lock nut.

   d. Close valve (part #1).

   e. Start pump/motor and run system until reservoir temperature gage reads normal operating temperature.

   f. Close load valve (part #3) until a pressure of 300 psi is obtained (compensator is set higher than 300 psi).

   g. Disconnect hydraulic circuit tester.

   h. Loosen maximum volume screw locknut.

   i. Connect hydraulic circuit tester as shown on TM-1.

   j. Stop pump/motor.

   k. Cycle system to check setting.

6. List the procedure for setting a pressure compensator.

   a.

   b.

   c.

   d.

   e.

   f.

   g.

   h.

   i.

7. Arrange in order the steps necessary to set a minimum volume stop.

   a. Start pump/motor and run system until reservoir temperature gage reads normal operating temperature.

   b. Close valve (part #1).

   c. Open load valve (part #3) all the way.

   d. Disconnect ammeter and hydraulic circuit tester.

e. Connect hydraulic circuit tester as shown on TM-1.

f. Close load valve (part #1) until ammeter shows pump has compensated.

g. Cycle system to check setting.

h. Loosen minimum volume screw locknut.

i. Adjust screw (usually clockwise to increase flow) to obtain desired setting.

j. Tighten minimum volume screw locknut.

k. Install ammeter across electric motor input leads.

l. Stop pump/motor.

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 4: TESTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS OF A VARIABLE VOLUME PRESSURE COMPENSATED PUMP

Answers to Evaluation Items:

1. a. It is compensated
   b. Can have minimum volume adjustments
   c. Can have maximum volume adjustments

2. a. Record motor speed __________ (Data from motor name tag or use handheld electronic tachometer)
   b. Connect the hydraulic circuit tester at point A shown on TM-1.
   c. Start electric motor and run system until reservoir temperature gage reads normal operating temperature.
   d. Open load valve (part #3) all the way.
   e. Close valve (part #1).
   f. Record pressure __________ psi
      flow __________ GPM
      @ no load.
   g. Close load valve until a pressure of 100 psi less than compensated pressure is reached.
   h. Record pressure __________ psi
      flow __________ GPM
   i. Open load valve
   j. Turn off system and disconnect hydraulic circuit tester.

3.1 a.

$$\text{P.E.} = \frac{3.75}{4.8} \times 100 = 78\%$$

b. $Q_S = 4.8 - 3.75 = 1.05$

3.2 Test data = 78%
Published data = 94%

4. a. Obtain and review pump manufacturer's maintenance manual for proper procedure and special instructions.
   b. Release any stored energy in machine, block up rams, etc., and turn off prime mover.
   c. Lock-out machine power, so it cannot be started accidentally.
   d. Wash (with approved solvent) the pump, all fluid lines, and fittings leading to the pump.
   e. Disconnect pump inlet, outlet, drain, and control lines.
   f. Disconnect pump from prime mover coupling.
   g. Remove pump from mounting bracket or pad.
   h. Clean (with approved solvent) mounting bracket or pad.
   i. Inspect mounting bracket or pad; repair or replace, if required.
   j. Remount new or repaired pump, using approved fastener. Torque bolts to correct torque value in the right sequence. (Drain

port, if pump has one, to top side.)

k. Check pump input shaft against prime mover shaft for correct alignment. Shim or realign as required.
l. Clean and inspect coupling. Replace if defective.
m. Install coupling.
n. Fill case drain (if pump has one) with hydraulic oil and rotate pump shaft by hand. Check for binding during rotation.
o. Connect pump input, output, and drain and control lines using approved fittings.
p. Restore power to machine and remove blocks as required.
q. Start-jog the pump and check 1) prime mover shaft rotation against pump shaft rotation. Arrow on pump body shows correct pump shaft rotation, and 2) noise - does the pump sound right?
r. Start-run the pump to circulate oil through the system at no load until correct operating temperature is reached.
s. Check fluid (pressure and drain) lines for leaks.
t. Check fluid inlet line(s) for air leaks.
u. Check maximum volume stop setting and adjust if necessary.
v. Check compensator setting and adjust if necessary.
w. Check minimum volume stop setting and adjust if necessary.
x. Induce load on system.
y Check:
    1. operating speed of actuators
    2. relief valve setting
    3. general machine condition
    4. oil level
    5. oil leaks
    6. noise - does all sound right?

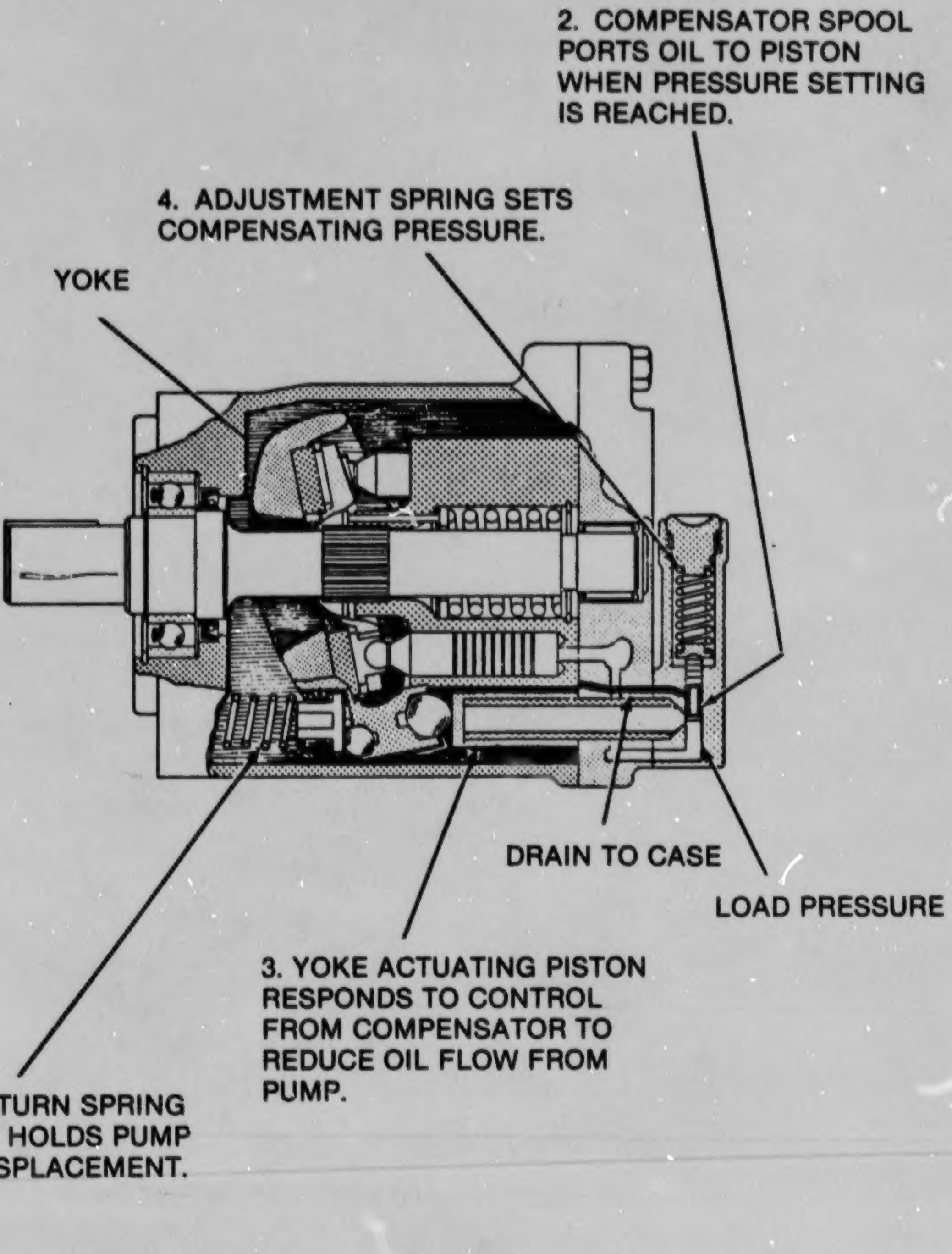
5. a. Connect hydraulic circuit tester as shown on TM-1.
b. Start pump/motor and run system until reservoir temperature gage reads normal operating temperature.
c. Open load valve (part #3) all the way.
d. Close valve (part #1)
e. Close load valve (part #3) until a pressure of 300 psi is obtained (compensator is set higher than 300 psi).
f. Loosen maximum volume screw locknut.
g. Adjust screw (usually clockwise for decreased flow) to obtain desired setting.
h. Tighten maximum volume screw lock nut.
i. Cycle system to check setting.
j. Stop pump/motor.
k. Disconnect hydraulic circuit tester.

6. a. Set compensator for maximum pressure (usually screwed in all the way).
b. Set system relief to relieve at lowest possible setting (usually screwed out almost all the way).
c. Start pump/motor and run system until reservoir temperature gage reads normal operating temperature.
d. Induce a load on the pump to produce pressure or use load valve on hydraulic tester, it is on system at this time.
e. Set system relief valve 150 to 200 psi higher than compensator setting (use system pressure gage to observe pressure, or hydraulic circuit tester).

f. Set compensator to desired value.
g. Tighten locknuts on compensator and relief valve.
h. Cycle system to check operation of compensator. An ammeter can be installed across electric motor input leads to show pump compensation.
i. Stop pump/motor.

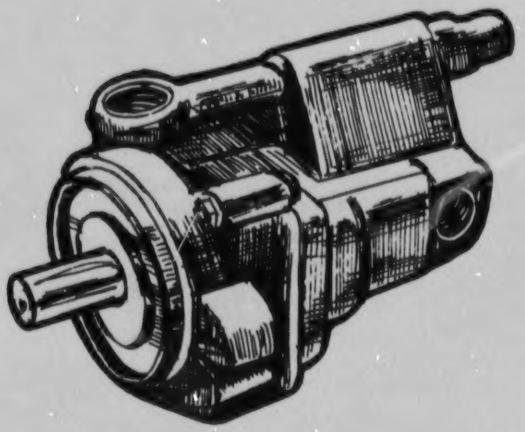
7. a. Install ammeter across electric motor input leads.
b. Connect hydraulic circuit tester as shown on TM-1.
c. Start pump/motor and run system until reservoir temperature gage reads normal operating temperature.
d. Open load valve (part #3) all the way.
e. Close valve (part #1).
f. Close load valve (part #1) until ammeter shows pump has compensated.
f. Loosen minimum volume screw locknut.
g. Adjust screw (usually clockwise to increase flow) to obtain desired setting.
h. Tighten minimum volume screw locknut.
i. Cycle system to check setting.
j. Stop pump/motor.
k. Disconnect ammeter and hydraulic circuit tester.

Cut-Away of Pressure Compensated Pump


2. COMPENSATOR SPOOL PORTS OIL TO PISTON WHEN PRESSURE SETTING IS REACHED.
4. ADJUSTMENT SPRING SETS COMPENSATING PRESSURE.
YOKE
DRAIN TO CASE
LOAD PRESSURE
3. YOKE ACTUATING PISTON RESPONDS TO CONTROL FROM COMPENSATOR TO REDUCE OIL FLOW FROM PUMP.
1. YOKE RETURN SPRING NORMALLY HOLDS PUMP AT FULL DISPLACEMENT.

Parker PAV 10 Pump Performance Chart

ENGINEERING PERFORMANCE DATA



SPEED
Minimum 100 RPM
Maximum 2300 RPM

PRESSURE
5000 PSI (350 Bar) Intermittent
4500 PSI (315 Bar) Continuous

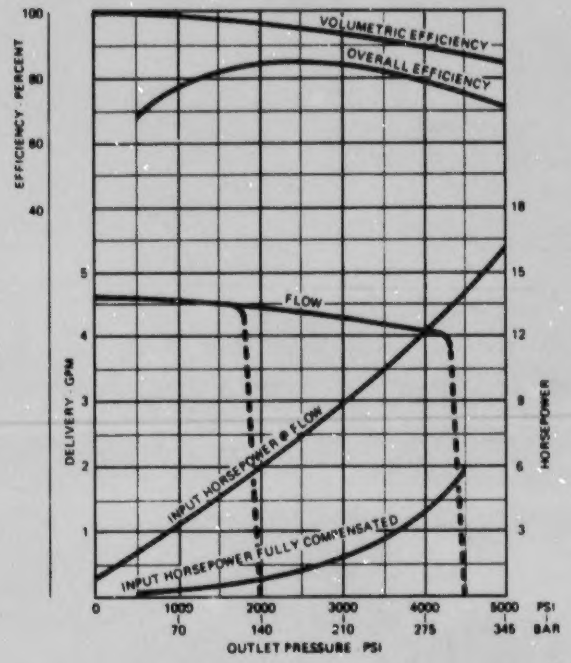
MAXIMUM FLOW
PAV 10 6.0 GPM (22.7 L/M)

QUICK REFERENCE DATA CHART

MODEL NUMBER	THEORETICAL DISPLACEMENT IN^3/REV. (CC/REV.)	DELIVERY GPM AT 100 PSI		*APPROX. NOISE LEVEL db(A) @ FULL FLOW 1800 RPM (1200 RPM)				APPROXIMATE HORSEPOWER AT MAXIMUM PSI, FLOW & 1800 RPM
		1200 RPM	1800 RPM	500 PSI	1500 PSI	2000 PSI	4500 PSI	
PAV 10	.61 (10)	3.2	4.8	69.5 (63.5)	70.5 (67.5)	71 (67.5)	72 (69.5)	16.0

*Since many variables such as mounting, tank style, plant layout, etc., effect noise levels, it cannot be assumed that the above readings will be equal to those in the field. The above values are for guidance in selecting the proper pump. The values indicated are "Free Field" sound pressure levels at a distance of three feet from the pump. The values are based on reverberatory room measurements.

BASED ON OIL TEMPERATURE OF 120° F (100 SSU)
1800 RPM - ATMOSPHERIC INLET



NOTE:
The efficiencies and data in the graph are good for pumps running at 1800 RPM on 100 SSU viscosity hydraulic oil. To calculate the approximate required driving horsepower for other conditions, use the following formula and chart:

$$HP = \left[\frac{\text{Actual GPM} \times \text{(PSI)}}{1714}\right] + CF$$

Actual GPM is proportional to drive speed and the maximum volume stop setting for variable pumps. Energy absorption of the pump is effected by speed and viscosity, but primarily by flow losses which are a function of pressure for normal stabilized operation. Therefore, the correction factors are based on pressure.

CORRECTION CHART

(PSI)	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
CF	.35	.55	.65	.90	1.1	1.6	1.8	2.2	3.0	4.1

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Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

Scope of Unit: After the completion of this unit, the student should be able to measure pressure and flow, and explain the process of troubleshooting. The student should be able to replace components, adjust them, check that they are operational, and complete the followup paperwork required for documentation. This knowledge will be evidenced by correctly performing the procedure outlined in the demonstration lessons and by scoring 85 percent or better on the evaluation items.

LESSON 5: ADJUST THE MAXIMUM VOLUME STOP, MINIMUM VOLUME STOP, RELIEF VALVE, AND PRESSURE COMPENSATOR ON A VARIABLE VOLUME PRESSURE COMPENSATED PUMP (DEMONSTRATION LESSON)

Lesson Objectives - the student should be able to:

1. Set a maximum volume stop on a pump.
2. Set a minimum volume stop on a pump.
3. Set a pressure compensator stop on a pump.
4. Set a relief valve on a pressure compensated circuit.
5. Demonstrate safe work habits.

Supplementary Teaching/Learning Items:

1. TM-1 Circuit Schematic

Informational Assignment: (Student)

Review Unit 2, Lesson 4

References: (Instructor's Additional Information)

Pump manufacturer's manuals

Introduction: This demonstration is to acquaint the student with one of the common jobs of maintenance personnel, the adjusting of a pressure compensated pump.

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 5: ADJUST THE MAXIMUM VOLUME STOP, MINIMUM VOLUME STOP, RELIEF VALVE, AND PRESSURE COMPENSATOR ON A VARIABLE VOLUME PRESSURE COMPENSATED PUMP

Tools, Equipment, and Materials:

Equipment shown on TM-1 and tong type ammeter

Steps of Procedure:

1. Identify components on the workbench that will be used.
2. Review published literature on components.
3. Assemble circuit shown on TM-1.
4. Have instructor check circuit.
5. Review safety precautions with instructor.
6. Open valve #1.
7. Open valve #3.
8. Set relief valve at maximum setting.
9. Start/jog the pump and check for:
    a) shaft rotation
    b) noise
    c) leaks
10. Start/run the pump to circulate oil through the pump until correct operating temperature is reached.

Now set maximum volume stop.

11. Loosen pressure compensator locknut.
12. Set pressure compensator to maximum.
13. Tighten pressure compensator locknut.
14. Close valve #1.

15. Close valve #3 until a pressure of 300 psi is shown on the pressure gage.

16. Loosen maximum volume locknut.

17. Adjust maximum volume screw until desired flow is achieved.

18. Tighten maximum volume locknut.

19. Open valve #3.

Now adjust relief valve

20. Loosen relief valve locknut.

21. Set relief valve at minimum pressure setting.

22. Close valve #3.

23. Adjust relief valve for 200 psi more than pressure compensator is to be set for.

24. Tighten relief valve locknut.

Now set pressure compensator.

25. Loosen pressure compensator locknut.

26. Adjust pressure compensator to desired setting.

27. Tighten pressure compensator locknut.

Now adjust minimum volume stop.

28. Open valve #3.

29. Stop pump/motor.

30. Install ammeter.

31. Start pump/motor.

32. Close valve #3 until flow is at its minimum volume required to maintain pressure and ammeter shows pump has compensated (this step also is a check that the pump does compensate).

33. Loosen minimum volume stop locknut.

34. Adjust minimum volume stop screw until desired flow is achieved.

35. Check to make sure pump is still compensated.

36. Tighten minimum volume stop locknut.

Recheck setting.

37. Open valve #3.

38. Is maximum volume being delivered?

39. Close valve #3.

40. Did pump compensate at desired pressure - verify with ammeter that the pump did compensate.

41. Open valve #3 slowly until the minimum volume desired is shown on flow meter.

42. Is pump still compensated?

43. If all is OK, show instructor or stop pump/motor.

44. Disconnect circuit.

45. Return equipment to proper places.

46. Clean up the work area.

Unit 2: Repair Machine Malfunctions

LESSON 5: ADJUST THE MAXIMUM VOLUME STOP, MINIMUM VOLUME STOP, RELIEF VALVE, AND PRESSURE COMPENSATOR ON A VARIABLE VOLUME PRESSURE COMPENSATED PUMP

Interaction Items: (Review Items)

1. Discuss what is happening inside the pump when each of these adjustments is made.
2. Discuss energy saving with this type of pump.
3. Relate energy use to ammeter reading.

Classroom, Laboratory, Shop, or Other Activities:

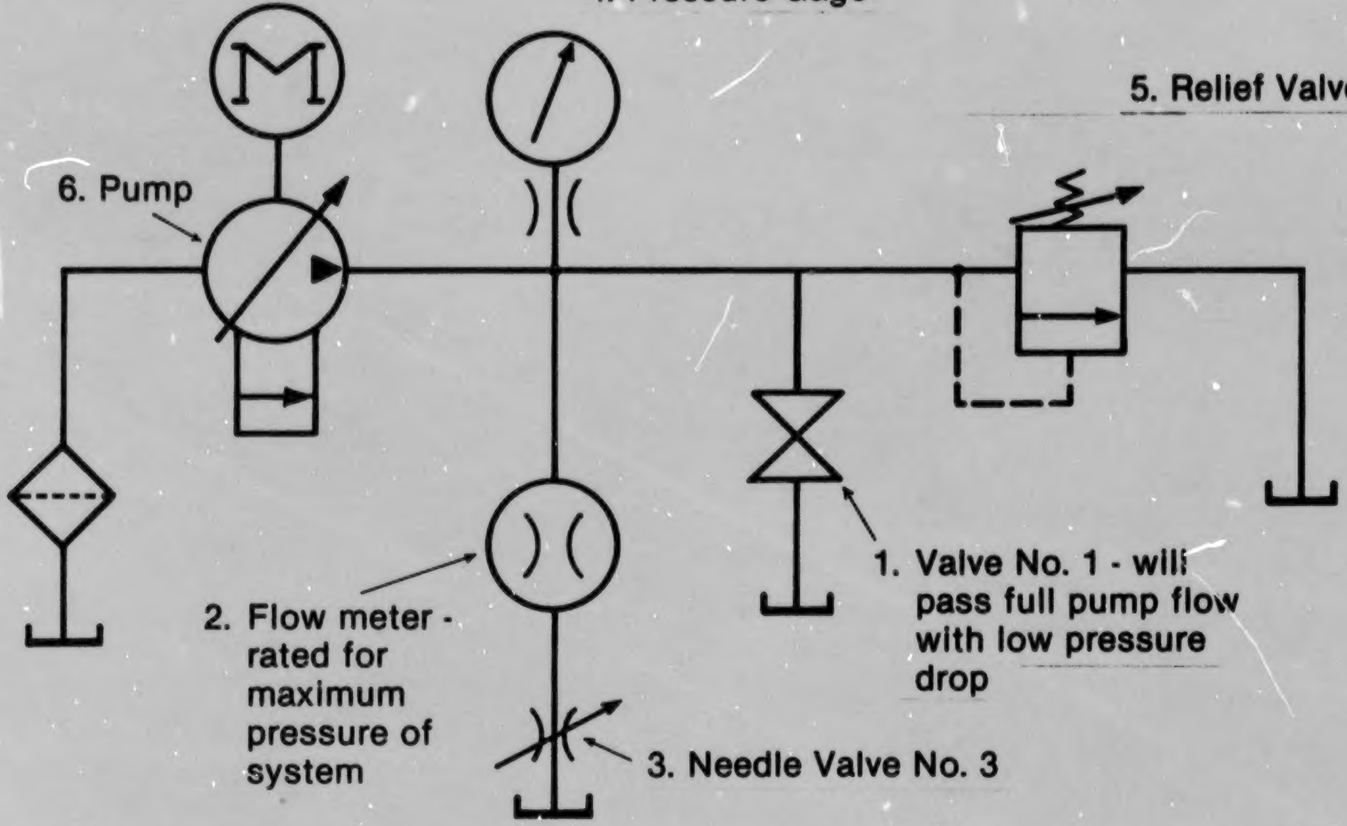
LESSON 5: ADJUST THE MAXIMUM VOLUME STOP, MINIMUM VOLUME STOP, RELIEF VALVE, AND PRESSURE COMPENSATOR ON A VARIABLE VOLUME PRESSURE COMPENSATED PUMP

Evaluation Items:

The student has satisfactorily completed the following steps of procedure:

1. Adjusted maximum volume stop.
2. Adjusted minimum volume stop.
3. Set pressure compensator.
4. Set relief valve.
5. Demonstrated safe work practices in performing the above steps.

Circuit Schematic



4. Pressure Gage

5. Relief Valve

6. Pump

2. Flow meter - rated for maximum pressure of system

1. Valve No. 1 - will pass full pump flow with low pressure drop

3. Needle Valve No. 3

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

Scope of Unit: After the completion of this unit, the student should be able to measure pressure and flow, and explain the process of troubleshooting. The student should be able to replace components, adjust them, check that they are operational, and complete the followup paperwork required for documentation. This knowledge will be evidenced by correctly performing the procedure outlined in the demonstration lessons and by scoring 85 percent or better on the evaluation items.

LESSON 6: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - SPOOL TYPE DIRECTIONAL CONTROL VALVES

Lesson Objectives - the student should be able to:

1. Match terms and definitions of valve parts.
2. Identify reasons why a valve spool will not shift.
3. Explain why a valve could function in the reverse direction.
4. List leak points in valves.
5. List possible adjustments on valves.
6. Recall inspection points on replacement parts.
7. Review the procedure for checking for correct operation of directional control valves.

Supplementary Learning/Teaching Items:

1. TM-1 Pilot Chokes

Informational Assignment: (Student)

Review Unit II, Lesson 14 - Components (Valves). IML Fluid Power/Basic Hydraulics

References: (Instructor's Additional Information)

Fluid Power/Basic Hydraulics. Columbia, MO: Instructional Materials Laboratory, 1983.

Introduction: Since there are many different styles of directional control valves, the maintenance personnel should review the manufacturer's bulletin before proceeding with any troubleshooting or adjustments.

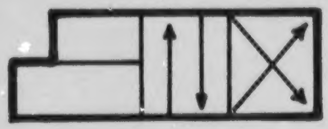
LESSON 6: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - SPOOL TYPE DIRECTIONAL CONTROL VALVES

Outline: (Key Points)

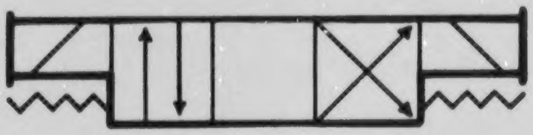
I. Definitions

A. Composite actuators and centering

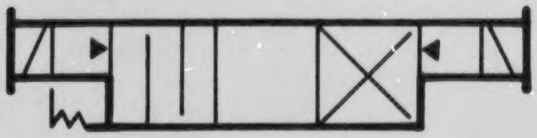
1. Solenoid with manual override and spring offset



2. Dual solenoid with manual override and spring centered



3. Solenoid controlled, oil pilot operated - detented with manual overrides



B. Parts of valves

1. Body - valve housing

2. Detent - device used to hold spool in position without a signal

3. Drain oil - internal leak oil from the valve

    a. internal - leak oil is returned to system inside valve.
    b. external - leak oil is returned to system remote from valve.
4. Manual override - part of the valve assembly that can be used to shift spool by hand
5. Pilot choke - metering valve used to control pilot oil
6. Pilot supply oil - oil used to shift main spool
    a. internal - supply comes from inside the valve.
    b. external - supply comes from outside the valve.
7. Pilot supply orifice plug - orifice installed in valve body to meter pilot oil supply
8. Signal light - light on solenoid that shows if power is applied to solenoid coil
9. Silting - buildup of fine particles (oil contaminants) on valve spool
10. Solenoid - electrical device used to shift spool in a directional control valve
11. Spool - the part of the valve that moves to direct flow through the valve body
12. Subplate - plate the piping connects into and valve body bolts onto

II. Troubleshooting valves - valve does not shift

A. Is there a signal to actuator?
    1. Signal light on for solenoid valve
    2. Mechanical limit made on manual valve

B. Will manual override button shift valve? If yes, valve is OK but
    1. No signal to solenoid
    2. Solenoid no good (If not, determine why.)
    3. Inadequate pilot oil supply, line flow, or pressure

C. Is pilot oil or pilot oil pressure available? Install gage in valve test port.
    1. Does pilot oil supply exist?

2. Are pilot chokes open?

3. Is pilot oil pressure high enough (75 psi minimum)?

For internal pilot supply

- a. Check tank line check valve.
- b. Check internal pilot check.
- c. Check for clogged pilot supply orifice plug.

For external pilot supply

- a. Check tubing to pilot.
- b. Check on pressure line check valve.
- c. Check for clogged pilot supply orifice plug.

D. Is valve bolted incorrectly to subplate?

1. Incorrect bolt tightness can cause body to warp, putting spool in bind.
2. Valve mounted on subplate in wrong position - is locating dowel pin installed?
3. O-rings in place between body and subplate

E. Silted valve spool - manually shift valve spool to face spool

F. Spool jammed

1. Foreign body lodged in spool cavity will prevent valve from shifting
2. Damaged internal parts - remove valve cap to inspect
    - a. return/centering springs
    - b. spring retainers
    - c. pistons
    - d. push pins
    - e. seals
3. Pilot drain line blocked - inspect drain line (both internal and external)

III. Troubleshooting valves - movement in wrong direction

A. Piping connected to A and B ports are backwards

- B. Wiring to solenoids is reversed

IV. Troubleshooting valves - leakage

- A. Leakage at subplate
    1. Pipe fitting loose - redope and tighten
    2. O-ring failure at interface between valve body and subplate - replace
    3. Body bolts loose - retorque
    4. Warped subplate on body
    5. Dirt at interface of valve body and subplate - clean
    6. Cracked subplate - replace
- B. Leakage at pilots or on body
    1. O-ring failure at face - replace
    2. Bolts loose - retorque
    3. Dirt at interface - clean
    4. O-ring failure on stroke adjustment screws - replace
    5. Test ports - redope and tighten
- C. Leakage at solenoids
    1. Seal failure at body - replace
    2. Seal failure at push rod - replace

V. Valve adjustments (not on all valves)

- A. Pilot chokes (TM-1)
    1. Loosen locknut.
    2. Turn screw clockwise to increase valve response time (shift speed).
    3. Check valve and system for shock.
    4. If OK, tighten locknut.

B. Spool stroke adjustments - limit spool travel

    1. Loosen locknut
    2. Turn screw clockwise to decrease valve shift
    3. Check for
        a. Desired flow
        b. Pressure drop
    4. Check for correct valve shift.
    5. Tighten locknut.

VI. Replace malfunctioning parts

A. Points to remember

    1. Consult parts manuals before disassembly of valve.
    2. Clean outer surface of valve with approved solvent before disassembly.
    3. Do all disassembly work on a clean workbench (dirt will contaminate parts).
    4. Cover all parts when not working on them to prevent contamination from airborne particles.
    5. Inspect all seals and sealing surfaces for nicks or scratches.
    6. Clean all parts with lint free towel before reassembly.
    7. Cap all ports on valve and piping at disassembly to prevent contaminants from entering valve on system.
    8. Inspect replacement parts for:
        a. Cleanliness
        b. Correct part numbers
        c. Correct assembly
        d. Nicks or burrs
        e. Correct fit

B. Replacing spools

    1. Inspect for nicks and scratches - stone lightly if necessary.

2. Clean and oil before reassembly.

3. Do not force spool into body.

4. Inspect valve spool bore for:

    a. Nicks and scratches

    b. Sharp edges

    c. Correct fit with spool

5. Check spool orientation.

VII. Check for proper operation - after valve has been assembled and system restored to operating condition

A. Inspect oil for contamination of fluid from defective valve.

B. Run system under no load to circulate oil and flush out entrapped air.

C. Cycle system (minimum 3 times) to check correct operation.

D. Check for fluid leaks.

E. Return later (1-3 hours) to again check for fluid leaks.

VIII. Points to remember

A. When disassembling valve (or anything with multiple parts) mark parts for correct orientation as they are taken apart so that they can be reassembled correctly.

B. Remember to install internal passage plugs (or leave out plugs) for correct internal/external pilot and drain as required.

LESSON 6: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - SPOOL TYPE DIRECTIONAL CONTROL VALVES

Interaction Items: (Review Items)

1. Discuss troubleshooting of different valves on shop equipment.
2. Stress cleanliness and correct handling procedure of spool.

Classroom, Laboratory, Shop, or Other Activities:

Disassemble valve in class to show parts and sealing surfaces.

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 6: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - SPOOL TYPE DIRECTIONAL CONTROL VALVES

Evaluation Items:

1. Match terms and definitions of valve parts.

_____ a. Body
_____ b. Spool
_____ c. Pilot choke
_____ d. Detent
_____ e. Solenoid
_____ f. Silting
_____ g. Signal light
_____ h. Manual override
_____ i. Subplate
_____ j. Pilot supply orifice plug
_____ k. Pilot supply oil
_____ l. Drain oil

1. Device used to hold spool in position without a signal
2. Metering valve used to control pilot oil
3. Electrical device used to shift spool in a directional control valve
4. Oil used to shift main spool
5. Light on solenoid that shows if power is applied to solenoid coil
6. Internal leak oil from the valve
7. Buildup of fine particles (oil contaminants) on valve spool
8. Part of the valve assembly that can be used to shift spool by hand
9. Valve housing
10. Plate which the piping connects into and valve body bolts onto
11. The part of the valve that moves to direct flow through the valve body
12. Orifice installed in valve body to meter pilot oil supply

2. Identify five reasons why a valve spool would not shift.

   a.

   b.

   c.

   d.

   e.

3. Explain why a valve could function in the reverse direction.

   a.

   b.

4. List three places where valves will leak.

   a.

   b.

   c.

5. What two adjustments may be possible on a directional control valve?

   a.

   b.

6. Replacement parts should be inspected for:

   a.

   b.

   c.

   d.

   e.

7. Review the "check for proper operation" procedure.

   a.

   b.

   c.

   d.

   e.

LESSON 6: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - SPOOL TYPE DIRECTIONAL CONTROL VALVES

Answers to Evaluation Items:

1. a. 9
   b. 11
   c. 2
   d. 1
   e. 3
   f. 7
   g. 5
   h. 8
   i. 10
   j. 12
   k. 4
   l. 6

2. a. No signal to valve
   b. No pilot oil or low pilot oil pressure
   c. Valve bolted incorrectly on subplate
   d. Silt
   e. Spool jammed

3. a. Piping connected incorrectly
   b. Wiring to solenoids reversed

4. a. At subplate
   b. At pilots or on body
   c. At solenoids

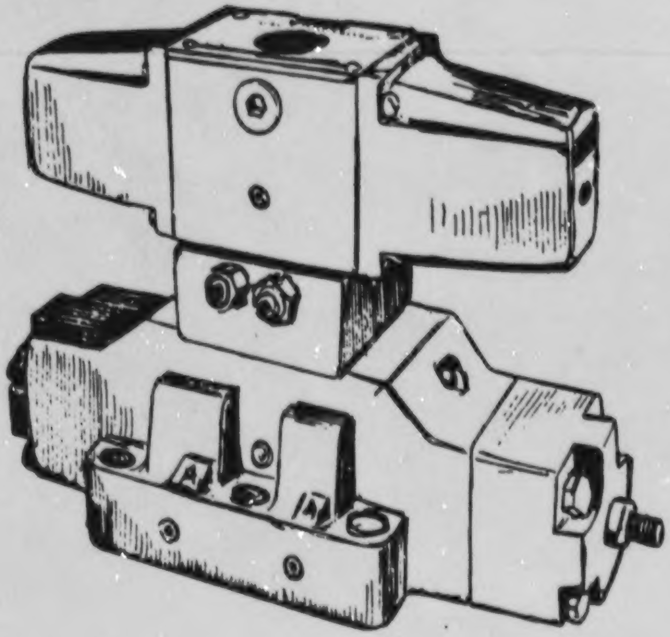
5. a. Pilot chokes
   b. Spool stroke adjustment

6. a. Cleanliness
   b. Correct part numbers
   c. Correct assembly
   d. Nicks or burrs
   e. Correct fit

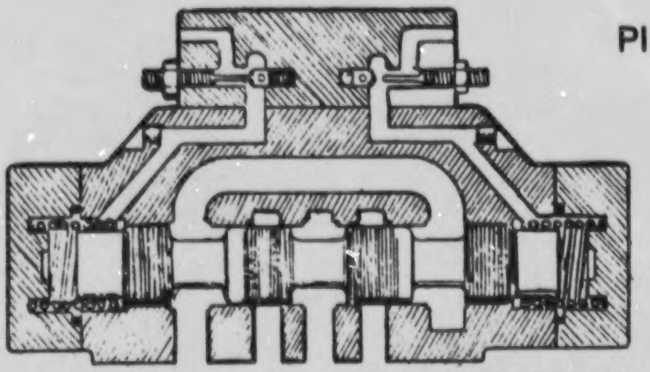
7. a. Inspect oil
   b. Run system under no-load to remove air
   c. Cycle system a minimum of 3 times
   d. Check for leaks
   e. Re-check for leaks

TM 1

Pilot Chokes


PILOT CHOKE BLOCK

Pilot Choke Mounted on DG3/DG5 Valve


PILOT CHOKE
DIRECTIONAL VALVE

Pilot Choke Controls Spool Movement

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

Scope of Unit: After the completion of this unit, the student should be able to measure pressure and flow, and explain the process of troubleshooting. The student should be able to replace components, adjust them, check that they are operational, and complete the followup paperwork required for documentation. This knowledge will be evidenced by correctly performing the procedure outlined in the demonstration lessons and by scoring 85 percent or better on the evaluation items.

LESSON 7: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - PRESSURE CONTROL VALVES

Lesson Objectives - the student should be able to:

1. Match terms and definitions associated with pressure control valves.

2.1 List items that should be checked when troubleshooting a relief valve.

2.2 List the steps of procedure for adjusting a relief valve.

3. Recognize in what position the adjusting screw should be set before beginning adjustments on a pressure reducing valve.

4. Recognize in what position the adjusting screw should be set before beginning adjustments on a counterbalance valve.

5. Recognize in what position the adjusting screw should be set before beginning adjustments on a sequence valve.

6. Recognize in what position the adjusting screw should be set before beginning adjustments on a brake valve.

7. Recognize in what position the adjusting screw should be set before beginning adjustments on an unloading valve.

8. List the procedure for checking for proper operation of pressure control valves.

9. List safety precautions to observe when setting pressure control valves.

Supplementary Teaching/Learning Items:

1. TM-1 "RC" Type Counterbalance Valve

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: Adjustments to pressure control valves will affect how a system operates. Before making any changes in pressure settings, consider their effects on the overall operation of the system.

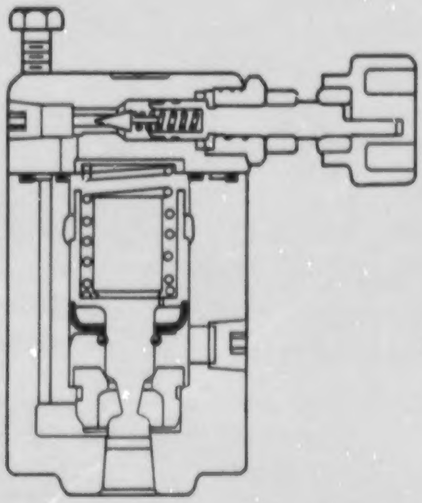
LESSON 7: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - PRESSURE CONTROL VALVES

Outline: (Key Points)

I. Definitions

- A. Check valve - valve which allows flow in one direction only
- B. Dart - same as a poppet
- C. Direct pilot - signal sensed internally in the valve body
- D. Main stage - section of valve which carries flow of system
- E. Pilot stage - section of valve which controls pilot signal
- F. Poppet - that part of a valve which prevents flow when it closes against a seat
- G. Relieving - state in which valve is diverting flow to the reservoir while maintaining system pressure (ex: relief valves relieve excess pressure)
- H. Remote pilot - signal sensed from another part of the system
- I. Unload - state in which valve is diverting flow to the reservoir at a low pressure (ex: unloading valve or vented relief valve)
- J. Vent - pilot signal diverted to reservoir

II. Relief valves



A. Troubleshooting - ask yourself:

1. Does turning the adjusting screw have an effect on system pressure?
2. Is valve adjusted correctly?
3. Is valve rated for the pressure and flow it is to control?
4. Is valve vented? If so, does this signal exist (compound type only)?
5. Remove and inspect poppet and seat. Is it OK?
6. Check spool for sticking. Is it OK?

B. Procedure for adjusting relief valves

1. Install pressure gage in system.
2. Loosen locknut on relief valve adjustment screw.
3. Screw adjustment screw out until no load is on dart spring.
4. Start pump/motor.
5. Induce load (actuate valve).
6. Turn adjustment screw in until desired pressure setting is reached.
7. Tighten adjustment screw locknut.
8. Cycle system to check for correct operation.
9. Shut pump/motor off.

III. Pressure reducing valves

A. Troubleshooting

(Note - A pressure reducing valve is the only normally open valve.)

1. Does turning adjusting screw have an effect on system pressure?
2. Is valve adjusted correctly?
3. Is valve rated for the pressure and flow it is to control?
4. Is system pressure high enough to be reduced to desired level?
5. Is drain line connected to tank, open, and free of obstructions?

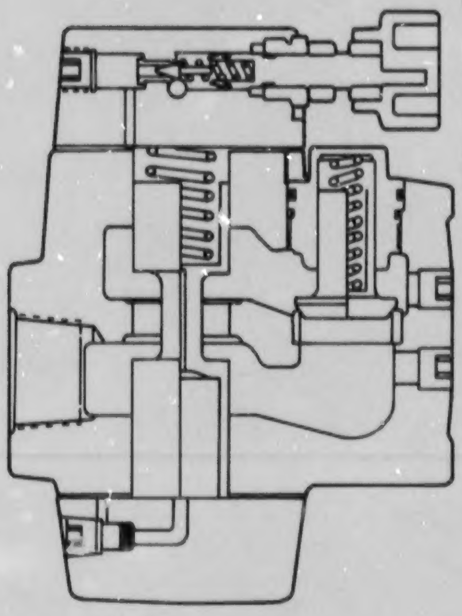
6. Is pilot connected to reduced pressure side of system?

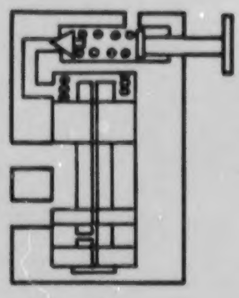
7. Remove and inspect poppet and seat. Is it OK?

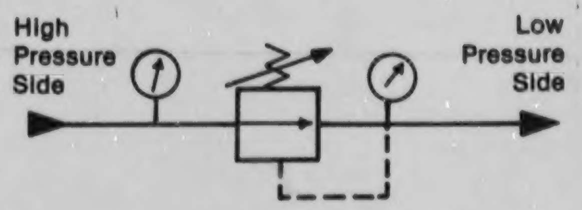
8. Remove and inspect check valve. Is it OK?

9. Check spool for sticking.

B. Procedure for adjusting pressure reducing valve







1. Install two pressure gages, one before and one after valve.
2. Loosen locknut on adjusting screw.
3. Screw adjustment screw out until no load is on dart spring.
4. Start pump/motor.
5. Induce a load (actuate valve).
6. Turn adjustment screw in until desired pressure is reached.
7. Check that system pressure is now higher than reducing valve setting.
8. Tighten adjusting screw locknut.
9. Cycle system to check for correct operation.
10. Shut off pump/motor.

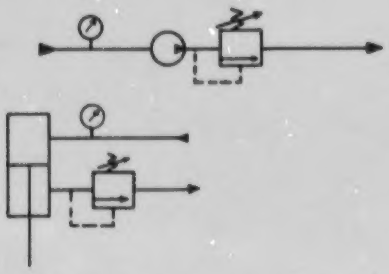
IV. Counterbalance valves (TM-1)

A. Troubleshooting

1. When turning adjusting screw does it have an effect on system pressure?
2. Is valve adjusted correctly?
3. Is valve rated for the pressure and flow it is to control?
4. Is drain line connected to tank, open, and free of obstructions?
5. Is pilot correct to load side of valve?
6. Remove and inspect poppet and seat. Is it OK?
7. Remove and inspect check valve. Is it OK?
8. Check spool for sticking.

B. Procedure for adjusting counterbalance valve

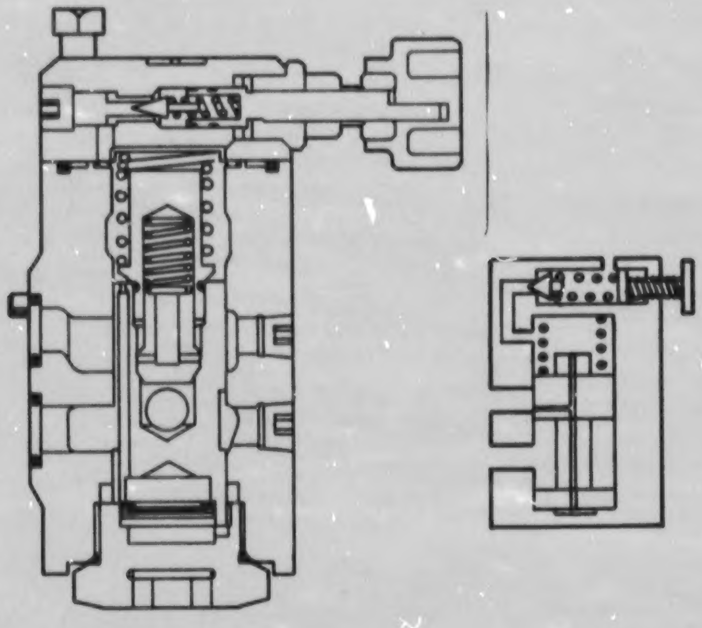
1. Install pressure gage before the actuator to be counterbalanced.



2. Load actuator to maximum load it will be subject to.
3. Loosen locknut on adjusting screw.
4. Screw adjustment screw in until maximum load is on spool spring.
5. Start pump/motor.
6. Induce a load (actuate valve).
7. Turn adjustment screw out until a pressure of 150 - 200 psi is shown on gage.
8. Tighten adjusting screw locknut.
9. Cycle system to check correct operation.

10. Shut off pump/motor.

V. Sequence valves



A. Troubleshooting - ask yourself:

1. Does turning adjusting screw have an effect on system pressure?

2. Is valve adjusted correctly?

3. Is valve rated for the pressure and flow it is to control?

4. Is system pressure high enough to cause sequencing?

5. Is external drain connected to tank, open, and free of obstructions?

6. Is pilot signal available?

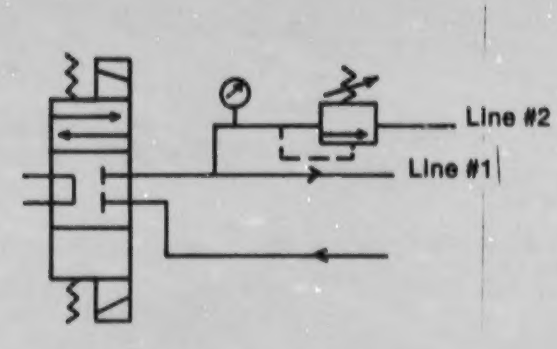
7. Remove and inspect poppet and seat. Is it OK?

8. Remove and inspect check valve. Is it OK?

9. Check spool for sticking.

B. Procedure for adjusting sequence valve

1. Install pressure gage before sequence valve.

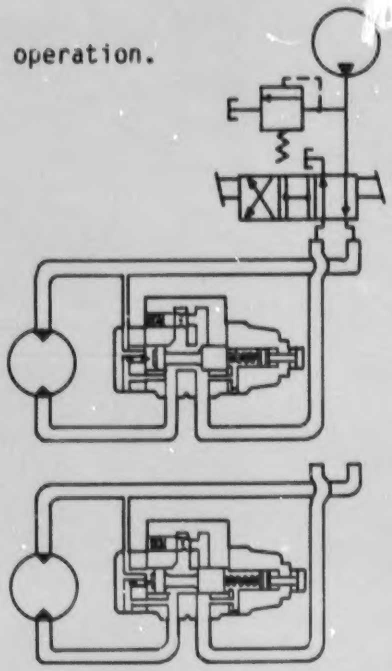


2. Load actuator on line 1.
3. Load actuator on line 2.
4. Loosen locknut on adjustment screw.
5. Screw adjustment screw in until maximum load is on spool spring.
6. Start pump/motor.
7. Induce a load (shift valve).
8. Turn adjustment screw out some.
9. Cycle system to observe at what gage pressure the valve does shift.
10. Repeat steps 8 and 9 until desired sequence pressure is achieved.
11. Tighten adjusting screw locknut.
12. Cycle system to check for correct operation.
13. Shut pump/motor off.

VI. Brake valves

A. Troubleshooting - ask yourself

1. When turning adjusting screw does it have an effect on system pressure?
2. Is valve adjusted correctly?
3. Is valve rated for the pressure and flow it is to control?
4. Is system pressure high enough to operate brake?



5. Are both internal and external pilot signals available?

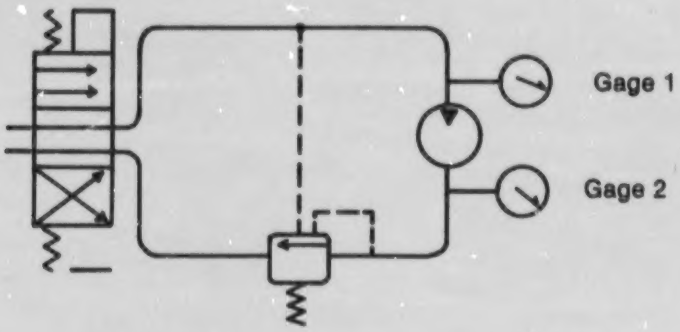
6. Remove and inspect poppet and seat. Is it OK?

7. Remove and inspect check valve. Is it OK?

8. Check spool for sticking.

B. Procedure for adjusting brake valve

1. Install two pressure gages.



2. Loosen locknut on adjustment screw.

3. Screw adjustment screw out until minimum load is on spool spring.

4. Start pump/motor.

5. Shift valve.

6. Motor should start to turn at a pressure above 100 psi.

7. Shift valve to center - motor should coast to a stop.

8. Screw adjustment screw in slightly.

9. Shift valve to start motor turning. When at normal speed, shift valve to stop motor (observe pressure on gage 2).

10. Repeat steps 8 and 9 until motor stops in desired amount of time.

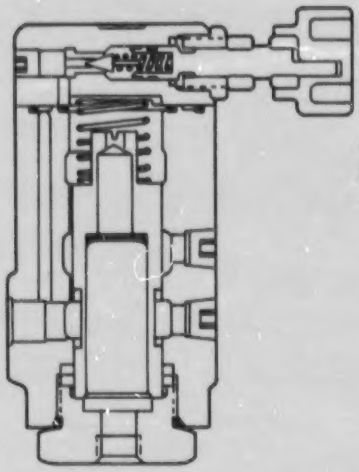
11. Pressure gage #2 should not show a reading higher than the maximum pressure rating of the motor.

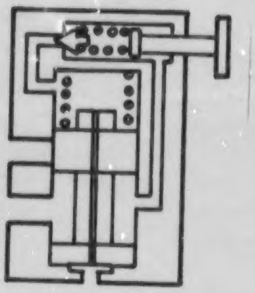
12. Tighten adjusting screw locknut.

13. Cycle system to check for correct operation.

14. Shut pump/motor off.

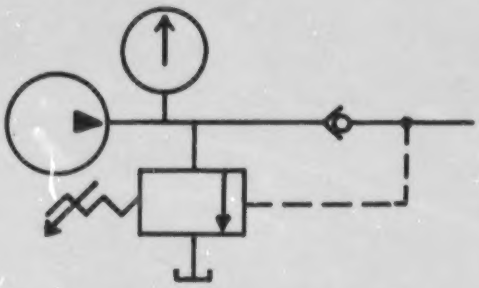
VII. Unloading valves





A. Troubleshooting - ask yourself:

1. When turning adjusting screw does it have an effect on system pressure?
2. Is valve adjusted correctly?
3. Is valve rated for the pressure and flow it is to control?
4. Is a pilot signal available?
5. Is the check valve installed correctly?



6. Is drain open?
7. Remove and inspect poppet and seat. Is it OK?
8. Remove and inspect check valve. Is it OK?
9. Check spool for sticking.

B. Procedure for adjusting unloading valve

1. Install gage as shown above in circuit.
2. Loosen locknut on adjusting screw.
3. Screw adjustment screw out until minimum pressure is on dart spring.
4. Start pump/motor.
5. Induce a load (actuate valve).
6. Screw adjustment screw in until desired pressure is shown momentarily on gage.
7. Tighten adjusting screw locknut.
8. Cycle system to check correct operation.
9. Shut pump/motor off.

VIII. Replacing and rechecking components

A. Replacing spools

1. Inspect for nicks and scratches - stone lightly if necessary.
2. Clean and oil before reassembly.
3. Do not force spool into body.
4. Inspect valve spool bore for:
    a. Nicks and scratches
    b. Sharp edges
    c. Correct fit with spool

B. Check for proper operation - after valve has been assembled and system restored to operating condition

1. Inspect oil for contamination of fluid from defective valve.
2. Run system under no load to circulate oil and flush out entrapped air.
3. Cycle system (minimum 3 times) to check correct operation.
4. Check for fluid leaks.
5. Return later (1-3 hours) to again check for fluid leaks.

IX. Safety precautions to observe when setting pressure valves

   A. Perform all work in a safe manner.

   B. Know system before making any adjustments.

   C. No system should be adjusted to operate at a pressure above the lowest pressure rating of any component.

LESSON 7: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - PRESSURE CONTROL VALVES

Interaction Items: (Review Items)

1. Discuss when and why each type of valve is used.
2. Discuss troubleshooting procedure in general.
3. Discuss importance of cleanliness when valves are disassembled.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 7: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - PRESSURE CONTROL VALVES

Evaluation Items:

1. Match terms and definitions associated with pressure control valves.

____ a. Check valve
____ b. Dart
____ c. Direct pilot
____ d. Main stage
____ e. Pilot state
____ f. Poppet
____ g. Relieving
____ h. Remote pilot
____ i. Unload
____ j. Vent

1. Same as a poppet
2. Section of valve which controls pilot signal
3. State in which valve is diverting flow to the reservoir at a low pressure (ex: unloading valve or vented relief valve)
4. That part of a valve which prevents flow when it closes against a seat
5. Pilot signal diverted to reservoir
6. Valve which allows flow in one direction only
7. State in which valve is diverting flow to the reservoir while maintaining system pressure (ex: relief valves relieve excess pressure)
8. Section of valve which carries flow of system
9. Signal sensed from another part of the system
10. Signal sensed internally in the valve body

2.1 List items that should be checked when troubleshooting a relief valve.

a.

b.

c.

d.

e.

f.

2.2 List procedure for adjusting a relief valve.

a.

b.

c.

d.

e.

f.

g.

h.

i.

3. On a pressure reducing valve, the adjusting screw should be screwed ________ before starting the adjustments.

4. On a counterbalancing valve, the adjusting screw should be screwed ________ before starting the adjustments.

5. On a sequence valve, the adjusting screw should be screwed ________ before starting the adjustments.

6. On a brake valve, the adjusting screw should be screwed ________ before starting the adjustments.

7. On an unloading valve, the adjusting screw should be screwed ________ before starting the adjustments.

8. List the procedure for checking for proper operation of pressure control valves.

a.

b.

c.

d.

e.

9. List safety precautions to observe when setting pressure control valves.

   a.

   b.

   c.

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 7: TROUBLESHOOTING, ADJUSTING, REPLACING, AND RECHECKING COMPONENTS - PRESSURE CONTROL VALVES

Answers to Evaluation Items:

1. a. 6
   b. 1
   c. 10
   d. 8
   e. 2
   f. 4
   g. 7
   h. 9
   i. 3
   j. 5

2.1 a. When turning adjusting screw does it have an effect on system pressure?
   b. Is valve adjusted correctly?
   c. Is valve rated for the pressure and flow it is to control?
   d. Is valve vented? If so, does this signal exist (compound type only)?
   e. Remove and inspect poppet and seat. Is it OK?
   f. Check spool for sticking. Is it OK?

2.2 a. Install pressure gage in system.
   b. Loosen locknut on relief valve adjustment screw.
   c. Screw adjustment screw out until no load is on dart spring.
   d. Start pump/motor.
   e. Induce load (actuate valve).
   f. Turn adjustment screw in until desired pressure setting is reached.
   g. Tighten adjustment screw locknut.
   h. Cycle system to check for correct operation.
   i. Shut pump/motor off.

3. Out

4. In

5. In

6. Out

7. Out

8. a. Inspect oil for contamination of fluid from defective valve.
   b. Run system under no load to circulate oil and flush out entrapped air.

c. Cycle system (minimum 3 times) to check correct operation.
d. Check for fluid leaks.
e. Return later (1-3 hours) to again check for fluid leaks.

9. a. Perform all work in a safe manner.
b. Know system before making any adjustments.
c. No system should be adjusted to operate at a pressure above the lowest pressure rating of any component.

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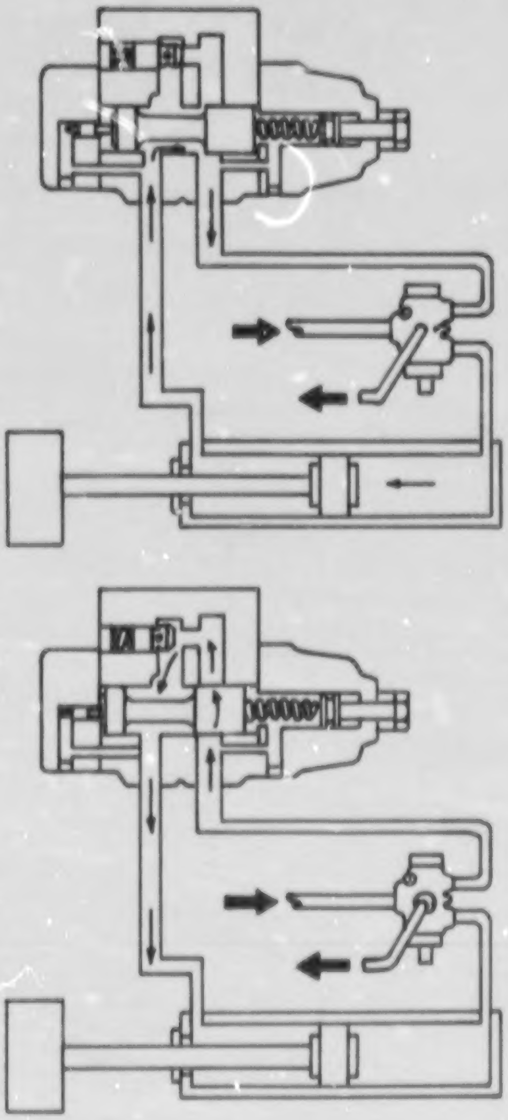
"RC" Type Counterbalance Valve



Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

Scope of Unit: After the completion of this unit, the student should be able to measure pressure and flow, and explain the process of troubleshooting. The student should be able to replace components, adjust them, check that they are operational, and complete the followup paperwork required for documentation. This knowledge will be evidenced by correctly performing the procedure outlined in the demonstration lessons and by scoring 85 percent or better on the evaluation items.

LESSON 8: DOCUMENT MACHINERY - PARTS AND HISTORY

Lesson Objectives - the student should be able to:

1.1 List the ten types of records which should be kept on equipment.

1.2 State three reasons for keeping equipment records.

2.1 Describe the maintenance/repair information which should be included in the equipment record.

2.2 Discuss how periodic lubrication and maintenance can be controlled.

2.3 State the purpose of a spare parts inventory list.

2.4 List the information which should be included in a spare parts inventory record.

2.5 State the reason for maintaining a cross-reference list of spare parts.

2.6 Name the seven items of information which should be in the work record for a piece of equipment.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: By maintaining a good record of a machine's history and replacement parts the maintenance department can function more efficiently.

Unit 2: Repair Machine Malfunctions

LESSON 8: DOCUMENT MACHINERY - PARTS AND HISTORY

Outline: (Key Points)

I. Equipment records - an overview

   A. Type of records to keep

      1. List of equipment in plant
      2. Sales information about equipment in plant
      3. Maintenance/repair information about equipment
      4. Purchase orders for machine and repair parts
      5. List of suppliers who furnish spare parts
      6. Periodic lubrication requirements and schedule
      7. Preventive maintenance requirements and schedule
      8. Inventory of spare parts in stock
      9. Cross-reference of similar parts
      10. What work has been performed on machine

   B. Reasons for keeping records - by keeping accurate records of the items listed above, the maintenance department can:

      1. React quickly to repair machine breakdowns because they:
         a. Have repair information available.
         b. Know what repair parts are available without a long search.
         c. Know where to obtain repair parts quickly.
      2. Perform lubrication and preventive maintenance when required because:
         a. Records tell what has to be done
         b. When to do it and what to see
         c. Remind maintenance department to perform work

3. Document:

    a. True cost of maintenance to keep machine in service

    b. Condition of machine

    c. Recurring problems of machine

    d. A recorded history of the machine

C. Dedication to keeping records - To have a meaningful and useful documentation program, everyone [plant manager(s), supervisor(s), maintenance personnel] must:

1. Understand the system.

2. Know the reasons why the system exists.

3. Make use of the system or support its use.

4. Keep records up to date.

II. The equipment record file should contain:

A. List of equipment in plant - Before any documentation on a piece of equipment can take place, a list of this equipment must be compiled. This listing should contain the following information:

1. Company's machine identification number (not machine model number)

2. Name of equipment

3. Equipment manufacturer

4. Model number

5. Serial number

6. Date of manufacture

7. Date of purchase

8. Capacity of equipment

9. Location of equipment in plant

B. Sales information - The machine file should contain a complete list of sales information. This information should be:

1. Copy of purchase order for machine

2. Copy of billing of machine purchase

3. Copy of machine warranty

4. Name, address, phone number of local company who sold machine and manufacturer of equipment

5. Name(s) of local sales company and equipment manufacturer sales and service managers and personnel

6. Complete copy of all sales literature that pertains to the machine

C. Maintenance/repair information - The machine file should contain a complete set of the following maintenance repair information:

1. Recommended spare parts list
2. Required preventive maintenance schedule
3. Required periodic lubrication schedule
4. Exploded part drawings and part list
5. Recommended disassembly/assembly procedure for major components
6. Correct adjustment procedures for components
7. Service bulletins on each component
8. Sequence of operation chart and/or booklet
9. Complete set of drawings

D. Spare part(s) purchase order - The machine file should contain a copy of the purchase order for each spare or replacement part that has been ordered. These purchase orders should contain the following information:

1. What was ordered and how many
2. Price
3. When part was ordered and when it was received
4. Where part was stored when it arrived
5. Supplier from whom part was ordered
6. What machine(s) part is for

E. List of suppliers - The machine file should contain a list of suppliers that can furnish replacement parts for the machine. This list should contain:

1. Supplier's name, mailing address, phone number

2. Contact person's name at the supplier's office

3. What parts they can supply

4. Emergency or night phone numbers (if available) of suppliers

5. Outside salesperson's name

F. Periodic lubrication

1. Requirements - The machine file should contain a list of lubrication requirements. This list is composed of:

    a. What parts are to be lubricated

    b. What type of lubricant to use

    c. How much lubricant to use

    d. How often parts are to be lubricated

2. Schedule - Some means should be set up to remind maintenance personnel (or machine operators) when to perform this required lubrication. Methods that are commonly used are:

    a. Card index file by weeks

    b. Yearly calendar filled in by week

    c. Weekly computer printout

    d. These reminders should either:

        1) State what machine is to be lubricated and refer maintenance personnel to the file for a list of what has to be done.

        2) State right on the reminder what has to be done.

    (Note - It is recommended that as this lubrication is performed, the person doing the work signs it off so a record can be kept showing that the work has been performed and by whom.)

G. Preventive maintenance

1. Requirements - The machine file should contain a list of the preventive maintenance items that must be checked to keep the machine in operation. This list is compiled by using the maintenance bulletins supplied with the machine when it was purchased.

2. Schedule - A means should be set up to remind maintenance personnel when to perform these functions. Methods that are commonly used are:

a. Card index file by weeks

b. Yearly calendar filled in by weeks

c. Weekly computer printout

d. These reminders should either:

   1) State what machine requires inspection and then refer maintenance personnel to the file for a list of what has to be done.

   2) State right on the reminder what has to be done.

(Note - It is recomended that as this work is performed, the person doing the work should sign it off so a record can be kept showing that the work has been performed and by whom.)

H. Spare parts inventory - A list of spare parts should be kept. This list should contain:

1. Name of part
2. Part number
3. Size (if necessary)
4. When it was purchased
5. Where and how it is used
6. How many are to be stocked, both maximum and minimum amounts
7. Quantity to be ordered
8. Where part is stored

I. Cross-reference of spare parts - To lower inventory cost it is necessary to store only the minimum number of parts required to keep a machine in operation. Since many pieces of equipment may use the same part(s), an inventory spare parts list should be started.

J. Record of work performed on machine - When any repair is performed on a piece of equipment, this repair should be fully documented and placed in the machine file. This documentation should contain the following information:

1. What was done
2. Why it was done
3. When it was done
4. By whom it was done

5. How long it took
6. Parts used
7. Any special observations or notes

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 8: DOCUMENT MACHINERY - PARTS AND HISTORY

Interaction Items: (Review Items)

1. Stress the importance of keeping good records.
2. Show the class a set of records kept on a piece of equipment in the classroom or shop.
3. Demonstrate how information can be entered directly into a computerized system.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 2: Repair Machine Malfunctions

LESSON 8: DOCUMENT MACHINERY - PARTS AND HISTORY

Evaluation Items:

1.1 List the types of records which should be kept on equipment.

a.

b.

c.

d.

e.

f.

g.

h.

i.

j.

1.2 Recall reasons for keeping records.

a.

b.

c.

2.1 What type of maintenance/repair information should be kept?

a.

b.

c.

d.

e.

f.

g.

h.

i.

2.2 Discuss how periodic lubrication and maintenance can be controlled.

2.3 Why should a spare parts inventory list be used?

2.4 What information should a spare parts inventory list contain?

a.

b.

c.

d.

e.

f.

g.

h.

2.5 State the reason for maintaining a cross-reference list of spare parts.

2.6 An equipment work record should contain the following information:

a.

b.

c.

d.

e.

f.

g.

LESSON 8: DOCUMENT MACHINERY - PARTS AND HISTORY

Answers to Evaluation Items:

1.1 a. Equipment in plant
    b. Sales information
    c. Maintenance/repair information
    d. Purchase order
    e. List of suppliers
    f. Lubrication requirements and schedule
    g. Preventive maintenance requirements and schedule
    h. Inventory of spare parts
    i. Cross-reference list
    j. Machine history

1.2 a. React quickly
    b. Perform required lubrication and maintenance
    c. Document history of machine

2.1 a. Spare part list
    b. Preventive maintenance schedule
    c. Periodic lubrication schedule
    d. Part drawings and list
    e. Disassembly/assembly procedure
    f. Adjustment procedures
    g. Service bulletins
    h. Sequence of operation list
    i. Complete set of drawings

2.2 A list of required items to be checked or performed should be made out and put in the file. Then some method of reminding the personnel to perform this work should be put in effect.

2.3 To lower inventory cost

2.4 a. Name of part
    b. Part number
    c. Size
    d. Purchase date
    e. How used
    f. Number to stock
    g. Order quantity
    h. Where it is stored

2.5 Many pieces of equipment use the same parts. A cross-reference list helps to lower inventory costs.

2.6 a. What was done
    b. Why was it done

c. When was it done
d. By whom was it done
e. How long did it take
f. Parts used
g. Special notes

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

Scope of Unit: After completion of this unit the student will be familiar with the correct test procedures to inspect components and component parts for reuse, and for documentation of the parts. The student should be able to discuss these procedures and score 85% on the evaluation items.

LESSON 1: PROPER REPAIR PROCEDURES

Lesson Objectives - the student should be able to:

1. Recall safety rules.
2. List safety precautions.
3. List types of information to review before performing a repair.
4. Discuss cleanliness.
5. List things to check for on replacement parts.
6. Recall what to do during a final inspection.
7. Review documentation.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: There is always a right and a wrong way to perform a task. There is always a hard way and an easy way to perform a job. The right way may not always be the easy way, but is worth the extra effort.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 1: PROPER REPAIR PROCEDURES

Outline: (Key Points)

I. Safety - The only way to perform a task is to do it in a safe manner.

  A. Safety is Rule #1

  B. Company (institution) work rules - All rules that are published by the company should be observed to the letter.

    1. There is a reason for every rule.

    2. You agreed to the rules and conditions when you accepted employment.

    3. Workers can and will be discharged if they do not follow the safety rules of the company by which they are employed.

  C. Endangering others - When you violate a work safety rule, you are not only endangering yourself but also everyone around you. Consider legal implications.

  D. Report unsafe conditions - As both an employee and a human being it is your moral obligation to report to the proper authorities (company, local, state, or federal) any unsafe practices that you observe.

  E. Common sense - Use common sense in performing any action. Stop and think what possible consequences could result from your action.

  F. Check work - The last action of any task you have undertaken is to check your work for correct and complete operation.

  G. Help - If you do not know what you are doing, ask for help and guidance. A lack of information can lead to unsafe work practices.

II. Safety precautions that should be observed:

  A. Observe warning signs - Check out the machine or equipment to see if any warning signs have been installed.

  B. Equipment manuals - Check through equipment manuals to see if any special safety precautions have to be followed.

C. Lock-out - All power (electric, air, etc.) to equipment should be disconnected and locked out with padlocks (before any work is performed) to prevent accidental startup.

D. Block-up any cylinder or other moving part before working on the system to prevent unexpected movement.

E. Discharge any power storage devices (accumulators, springs, etc.) to prevent unexpected movement.

F. Personal warning - Before work is to be performed on a piece of equipment ask the following questions and act if necessary.

   1. Should signs be erected to warn people that maintenance is being performed (ex. "Caution - Workers Above" or "Do Not Use Tags")?

   2. Should area be roped off?

G. Helper - Always consider having someone else around when work is being performed to:

   1. Assist with work.

   2. Provide a fire watch if required.

   3. Go for help or administer first aid if the unthinkable does happen.

H. Use of air - Never, under any conditions, pressurize a component with air to force it apart for disassembly.

III. Information - Never start any repair or overhaul on any piece of equipment until the following items have been reviewed:

A. Instructions - Always be informed as to what work is to be performed and how. Consult with the:

   1. Supervisor or Customer - What are their instructions?

   2. Work order - What does it say?

B. Equipment file - This file, which was discussed in Unit 2 Lesson 8 of this series, should be looked over before any work is started.

C. Equipment manuals - These should be reviewed and kept at the work station during the repair operation.

D. Consult with others - If someone is available who has performed this work before, they should be consulted for any "words of wisdom" before the task is performed.

E. Telephone - When in doubt, ask. Call the factory or manufacturer's local representative if any problems are encountered or advice is required.

IV. Cleanliness - Most hydraulic components have very small working clearances (.001 inches or less) that can become damaged by any small piece of foreign matter. The following practices should always be observed when working on hydraulic components.

A. Tools should be free of any dirt, grease, or foreign contaminants.

B. Work area should be free from:

    1. Dirt and contaminants on work surface

    2. Airborne particles

    3. Obstructions that can damage parts

C. Use only lint free paper towels; rags and shop towels are not an acceptable substitute as they may contain loose lint fibers.

V. Inspection of parts - During any repair/overhaul that requires the replacement of parts or components the following items should be checked:

A. Are they the correct parts?

B. Proper storage - Were parts stored in a manner that would guarantee their correct operation?

C. Are they within the useful life span? Is code data or life data correct?

D. Do they look all right?

    1. Dirt free?

    2. No nicks or scratches?

    3. No surface rust?

E. Do parts have to be tested before use?

VI. Final inspection - After overhaul work has been performed the following operations should be completed:

A. Performance test the entire system for correct operation.

B. Inspect all hardware for correct assembly.

C. Remove tools, excess parts, trash, etc., from equipment and clean up the work area.

D. Visually inspect equipment to determine that nothing has been overlooked.

VII. Documentation - Before any overhaul can be considered, complete the following paperwork.

A. Sign-off of any inspection tags or check points.

B. Equipment file - All pertinent data must be entered in file.

C. Reorder spare parts that have been used to keep stock at correct levels.

D. Report - Write and submit a detailed report (if it is required) for all interested parties.

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 1: PROPER REPAIR PROCEDURES

Interaction Items: (Review Items)

1. Discuss how this section would apply to a specific piece of equipment with which the students are familiar.
2. Discuss the safety rules in your shop.
3. Discuss why safety is so important.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 1: PROPER REPAIR PROCEDURES

Evaluation Items:

1. Fill in the blank:

   a. Safety is ______________.

   b. Give three reasons for following company work rules.

      1)

      2)

      3)

   c. Write a brief statement describing how and why each of these safety rules should be observed.

      1) Don't endanger others -

      2) Report unsafe conditions -

      3) Use common sense -

      4) Check your work -

      5) Get help -

2. List seven safety precautions that should be observed in the shop.

   a.

   b.

   c.

   d

   e.

   f.

   g.

3. What information sources should be consulted before starting a repair?

   a.

   b.

   c.

   d.

4. Make a statement about cleanliness for each of the following items.

   a. Tools -

   b. Work area - should be free of

      1)

      2)

      3)

   c. Paper towels -

5. Replacement parts should be checked for compliance with what before use?

   a.

   b.

   c.

   d.

   e.

6. A final inspection should consist of the following:

   a.

   b.

   c.

   d.

7. What items should be documented after a repair has been performed?

   a.

   b.

   c.

   d.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 1: PROPER REPAIR PROCEDURES

Answers to Evaluation Items:

1. a. Rule #1
   b. 1) Have a reason for making them
      2) You agreed to them
      3) Can be dismissed if not followed
   c. 1) When a work rule is violated it can hurt not only the person who breaks the rule but someone else
      2) It is a moral obligation to report unsafe conditions
      3) Think about what you are going to do before you do it
      4) Always inspect what has been done
      5) Ask if you do not know
2. a. Observe warning signs
   b. Use equipment manuals
   c. Block-up equipment
   d. Discharge power source
   e. Create personal warning signs
   f. Lock-out power
   g. Work with someone around
3. a. Equipment file
   b. Equipment manuals
   c. Others who have performed work, if possible
   d. Supplier if problems are encountered
4. a. Should be free of dirt and particles
   b. 1) Dirt
      2) Airborne contaminants
      3) Obstructions to damage parts
   c. Use only lint free types; never rags
5. a. Correct parts
   b. Proper storage
   c. Date code
   d. Appearance
   e. Need to test
6. a. Performance test
   b. Hardware inspection
   c. Misplaced tools and trash
   d. Visual inspection

7. a. Sign-off of inspection tags
   b. Equipment file
   c. Re-order spare parts
   d. Write a report if required

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

Scope of Unit: After completion of this unit the student will be familiar with the correct test procedures to inspect components and component parts for reuse, and for documentation of the parts. The student should be able to discuss these procedures and score 85% on the evaluation items.

LESSON 2: REMOVE, DISASSEMBLE, ASSEMBLE, AND REINSTALL HYDRAULIC COMPONENTS

Lesson Objectives - the student should be able to:

1. Recall safety precautions.

2. List steps necessary to remove a component from the system.

3. Discuss the correct disassembly of a component.

4. Discuss the correct assembly of a component.

5.1 Recall what to do if a sealing surface has a burr.

5.2 Recall what to check when installing seals.

6. Repeat the steps to perform when checking for correct operation.

7. Identify the final step after installing a component on a system.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: The following Lesson Plan is a general listing of things to do, look for, and remember when removing, disassembling, reassembling, and installing hydraulic components.

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 2: REMOVE, DISASSEMBLE, ASSEMBLE, AND REINSTALL HYDRAULIC COMPONENTS

Outline: (Key Points)

I. Safety - Before any component is removed from a hydraulic system the following must be done.

   A. System is shut down and power removed.

   B. Lock-outs installed

   C. Equipment blocked

   D. Stored energy in system released (air and hydraulic pressure, springs, etc.).

   For a discussion on these and other safety information, see Unit 3, Lesson 1 of this series.

   Remember: Safety is Rule #1

II. Removal of a component from a system

   A. Clean component and area around it with an approved solvent to remove accumulated dirt.

   B. Mark with matching wire number tags and disconnect any electrical power and control wires.

   C. Remove any piping attached to component and mark where it was attached (if necessary). Be careful to prevent siphoning from reservoir.

   D. Block off fluid lines with pipe plugs and caps to keep oil in and contamination out of system.

   E. Remove component mounting bolts.

   F. Mark component mounting orientation and then remove.

   G. Remove any loose seals from component or mounting surface - Place in box for safekeeping if seals must be reused.

   H. Install plastic or metal pipe plugs and caps in all component openings to prevent dirt from entering components.

   I. Reinstall mounting bolts (to prevent loss of same).

J. Cover mounting surface (if exposed) to prevent damage.

III. Disassemble component

A. Consult component maintenance and parts breakdown sheets for any:

1. Special instructions or warnings
2. List of special tools required, if any
3. Diagrams of what to expect when component is disassembled (ex. spring loaded components, left hand threads, etc.)

B. Clean:

1. Work area that will be used
2. Tools that will be used
3. Components

C. Match - mark component parts before disassembly.

D. Record any adjustments that can be measured (ex. adjustment screw protrudes 11/32" past jam nut).

(Note - Record means write it down.)

E. Loosen and remove parts, marking each as it is removed.

F. Place parts in clean containers to prevent loss and damage. Keep bolts and screws in taped holes. Keep nuts, washers, etc. on bolts or screws.

G. Remove any used thread sealant from pipe threads.

Caution: Use the proper tools for all work:

1. Sockets and wrenches, not pliers, to remove thread fasteners
2. The correct type and size of screwdriver

(Note - At this point parts should be inspected. This procedure is described in detail in Unit 3, Lesson 4 of this guide.)

IV. Assemble Component

A. Consult maintenance manual for correct procedure.

B. Clean each part with a lint free paper towel before use.

C. Inspect each part for any damage.

D. Lubricate (as required) each part as it is installed.

E. Install and tighten threaded fasteners:

    1. With correct tools
    2. To proper torque value
    3. In correct tightening sequence
    4. With washers and/or lock washers as required

  F. Roughly set adjustments that were recorded during disassembly.

  G. Inspect workmanship.

  (Note: Components should be tested at this point, as outlined in Unit 3, Lesson 7 of this guide.)

V. Reinstall component

  A. Clean and inspect mounting and sealing surface(s).
    1. On sealing or mounting surface with nicks and burrs, lightly stone (if necessary) with a red india type stone.
    2. Coat sealing surfaces with a light film of clean oil of the type used in the system.

  B. Install new seal(s) - Take care to insure that seal(s) are not pinched or folded over. As a general rule it is advisable to always use new seal(s).

  C. Mount component - Use reference marks that were made in Step F of Part II.

  D. Install and tighten threaded fasteners:
    1. With correct tools
    2. To proper torque value
    3. In correct tightening sequence
    4. Using washers and/or lock washer as required.

  E. Clean piping, removing any used thread sealant from pipe threads.

  F. Inspect piping and threads for damage; replace as required.

  G. Apply the correct pipe thread sealant and install fluid lines.

  H. Connect electrical power and control wires as required. Make use of number tags installed in step B of part II.

  I. Fill component (if necessary) with system fluid.

  J. Lubricate component (if necessary) with correct lubricant - consult maintenance manual.

K. Inspect workmanship.

VI. Inspect for correct operation

A. Start-jog the pump - if all is all right, proceed.

B. Start-run the pump to circulate oil through the system at no load until correct operating temperature is obtained.

C. Check fluid (pressure and drain) lines for leakage.

D. Check sealing surfaces for leakage.

E. Induce load on system.

F. Repeat Step C.

G. Repeat Step D.

H. Cycle system and check for correct operation.

I. Check over rest of system to see if there is any other work that should be performed.

VII. Documentation - After any component is replaced on a system the correct data must be entered in the file. See Unit 2, Lesson Plan 8 of this series for a discussion on this subject.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 2: REMOVE, DISASSEMBLE, ASSEMBLE, AND REINSTALL HYDRAULIC COMPONENTS

Interaction Items: (Review Items)

1. Discuss how this section could apply to a component with which the student is familiar.
2. Discuss the importance of the proper tools on a job.
3. Discuss how the lack of cleanliness will affect a system if contamination is allowed to enter system during the replacement of a component.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 2: REMOVE, DISASSEMBLE, ASSEMBLE, AND REINSTALL HYDRAULIC COMPONENTS

Evaluation Items:

1. List four major safety items that must be performed before a component is removed from a system.

   a.

   b.

   c.

   d.

2. Repeat the steps that are required to remove a component from a system.

   a.

   b.

   c.

   d.

   e.

   f.

   g.

   h.

   i.

   j.

3. Discuss the correct disassembly of a component.

   a.

   b.

   c.

   d.

   e.

f.

g.

4. Discuss the correct assembly of a component.

a.

b.

c.

d.

e.

f.

g.

5.1 What should be done if a sealing surface has a burr?

5.2 When installing seals care must be taken to prevent what?

6. List the steps to inspect for correct operation.

a.

b.

c.

d.

e.

f.

g.

h.

i.

7. After a component is installed on a system, what is the last thing that must be done?

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 2: REMOVE, DISASSEMBLE, ASSEMBLE, AND REINSTALL HYDRAULIC COMPONENTS

Answers to Evaluation Items:

1. a. System turned off - power removed
   b. Lock-outs installed
   c. Equipment blocked
   d. Release stored energy

2. a. Clean component and area around it
   b. Mark wires
   c. Remove piping
   d. Block off piping
   e. Remove mounting bolts
   f. Mark component orientation and remove component
   g. Remove seals
   h. Cap off opening in component
   i. Reinstall mounting bolt
   j. Cover mounting surface

3. a. Consult component maintenance and parts breakdown sheets for any:

      1) Special instructions or warnings
      2) List of special tools required, if any
      3) Diagrams of what to expect when component is disassembled (ex. spring loaded components, left hand threads, etc.).

   b. Clean:

      1) Work area that will be used
      2) Tools that will be used
      3) Component again

   c. Match - mark component parts before disassembly.
   d. Record any adjustments that can be measured (ex. adjustment screw protrudes 11/32" past jam nut).
   e. Loosen and remove parts, marking each as it is removed.
   f. Place parts in clean containers to prevent loss and damage. Keep bolts and screws in taped holes. Keep nuts, washers, etc. on bolts or screws.
   g. Remove any used thread sealant tape or dope from pipe threads. Caution: Use the proper tools for all work:

      1) Sockets and wrenches, not pliers, to remove threaded fasteners.
      2) The correct type and size of screwdriver.

4. a. Consult maintenance manual for correct procedure.
   b. Clean each part with a lint free paper towel before use.
   c. Inspect each part for any damage.
   d. Lubricate (as required) each part as it is installed.

e. Install and tighten threaded fasteners:

    1) With correct tools
    2) To proper torque value
    3) In correct tightening sequence
    4) With washers and/or lock washers as required

f. Roughly set adjustments that were recorded during disassembly.
g. Inspect workmanship.

5.1 Lightly stone with a red india type stone

5.2 That they are not pinched or folded over

6. a. Start-jog pump
   b. Start-run pump to warm oil
   c. Check for leaks in piping
   d. Check for leaks at sealing surfaces
   e. Induce load
   f. Check for leaks in piping
   g. Check for leaks at sealing surfaces
   h. Cycle system and check for correct operation
   i. Check rest of system

7. Document the file

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

Scope of Unit: After completion of this unit the student will be familiar with the correct test procedures to inspect components and component parts for reuse, and documentation of the parts. The student should be able to discuss these procedures and score 85% on the evaluation items.

LESSON 3: CHECKING TOLERANCE ON PARTS

Lesson Objectives - the student should be able to:

1. Explain how to prepare parts before checking tolerance.

2.1 Explain how to measure a valve spool.

2.2 Explain how to check for valve spool camber.

3. Explain how to measure a valve body bore.

4. Explain how to calculate diametrical clearance.

5. Discuss spool repair.

6. Discuss valve body bore repair.

7. Explain how to measure piston joint end play.

8. Explain how to measure flatness.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: Before any tolerance can be checked the part must be absolutely clean and degreased. Calibration of all measuring equipment must also be checked to obtain accurate, usable measurements.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 3: CHECKING TOLERANCE ON PARTS

Outline: (Key Points)

I. Preparing parts for tolerance testing

  A. Clean part with an approved solvent.

  B. Wipe clean with a lint free paper towel.

  C. Inspect part for, and remove, any small burrs or nicks by stoning with a red india type stone.

  D. Clean and wipe dry again, if part had to be stoned.

II. Measuring valve spools and checking for valve spool camber

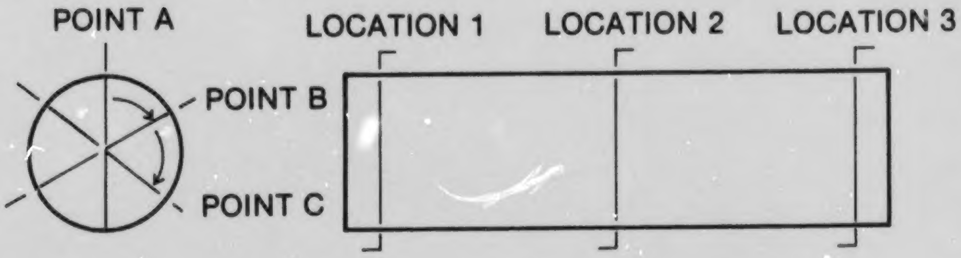
  A. Measuring valve spools - the following procedure can be used when valve spools or other close tolerance cylindrical parts are to be measured.

    1. Let part temperature stabilize to 68 - 72°F.

    2. Use a vernier micrometer capable of measurements to 0.0001 inch.

    3. Check calibration of micrometer with a gage block or constant.

    4. Measure part diameter at 9 locations as shown in the drawing below and record information (to four decimal places) on a table as shown.



Readings - Recorded to four decimal places at each location and average for each location

1A ______________ 2A ______________ 3A ______________

1B ______________ 2B ______________ 3B ______________

1C ______________ 2C ______________ 3C ______________

Average at Location 1: ______________

Average at Location 2: ______________

Average at Location 3: ______________

Average Diameter at Each Location is $= \frac{1A + 1B + 1C}{3}$ or $\frac{2A + 2B + 2C}{3}$ or $\frac{3A + 3B + 3C}{3}$

5. Calculate out of roundness and record findings.

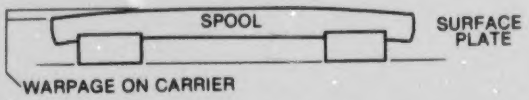
Out of roundness = Largest value - Smallest value at a location

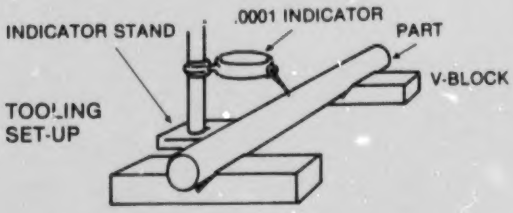
Record out of roundness at each location.

O.R. @ 1 __________ O.R. @ 2 __________ O.R. @ 3 __________

B. Check for warpage or camber of spool.

1. Clean surface plate, indicator stand and V-blocks.
2. Place valve spool on V-blocks one under each end.
3. Mount a 0.0001 inch division dial indicator in indicator stand.
4. Zero indicator on end of spool (zero reading is a high point of spool).
5. Pass indicator over the center of spool valve and record reading.


SPOOL
SURFACE PLATE
WARPAGE ON CARRIER


INDICATOR STAND
.0001 INDICATOR
PART
V-BLOCK
TOOLING SET-UP

(Note - This entire procedure can be used on pistons from piston pumps.)

III. Measure valve body bore or piston bores

The following procedure can be used to measure bores on valve bodies and pistons on axial piston motors or radial and axial piston type pumps.

A. Clean parts with an approved solvent.

B. Wipe clean with a lint free paper towel.

C. Inspect part for, and remove, any small burrs or nicks in the bore by stoning with a red india type stone. A round cross-section shaped stone works best for this type of part.

D. Clean and wipe dry again, if part had to be stoned.

E. Let part temperature stabilize to 68-72°F.

F. Measure part.

1. Use a vernier micrometer capable of measurements to 0.0001 inch to measure transfer gages.

2. Check calibration of micrometer with a gage block or constant.

3. For transfer gages use:

    a. Inside micrometer, or

    b. Telescoping gage, or

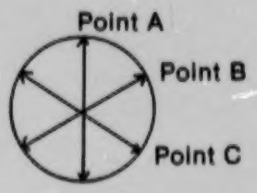
    c. Small hole gage on small valves

        1) Ball, or

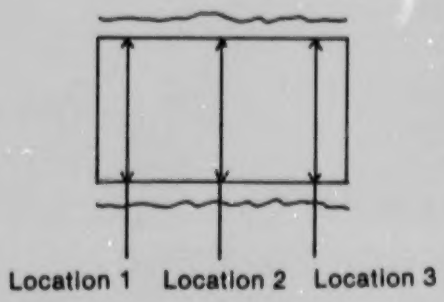
        2) Sliding wedge type

4. Take measurement at nine locations per drawing shown below and record information on a table as shown to four decimal places.

front view



side view



Readings - Recorded to four decimal places at each location and average for each location

1A ______________ 2A ______________ 3A ______________

1B ______________ 2B ______________ 3B ______________

1C ______________ 2C ______________ 3C ______________

Average at Location 1: ______________

Average at Location 2: ______________

Average at Location 3: ______________

Average Diameter at Each Location is

$$= \frac{1A + 1B + 1C}{3} \text{ or } \frac{2A + 2B + 2C}{3} \text{ or } \frac{3A + 3B + 3C}{3}$$

G. Calculate out of roundness and record findings.

Out of roundness = Largest value - Smallest value at a location

Record out of roundness at each location.

O.R. @ 1 __________ O.R. @ 2 __________ O.R. @ 3 __________

Note: This procedure can be used to measure piston pump piston bores.

IV. Fit of spool to body bore (diametrical clearance):

A. To determine the amount of diametrical clearance between spool and bore of valve use the following equation.

Diametrical Clearance = Average Maximum Bore Diameter - Average Minimum Spool Diameter

Average maximum bore diameter is largest average value obtained when bore was measured.

Average minimum spool diameter is smallest average value obtained when spool was measured.

B. Acceptable diametrical clearance

1. Consult manufacturer's catalog for this value.
2. If the maximum diametrical clearance value cannot be obtained from the manufacturer, use a value of 0.001 inch maximum.

V. Spool repair

A. Tools

1. When stoning spools, use a red india type stone for burr and nick removal.

2. Use an Arkansas hard white stone to remove fine scratches and to polish out marks left by red india stone.

3. Oil control grooves on spools should be cleaned of accumulated sludge and contamination buildup. Use a thin wood stick. Never use a steel object as damage can result.

B. Size - It is not practical to repair spools if they are worn undersize, badly damaged, or valve body is oversize.

1. Normally a worn spool is discarded and a new spool is ordered to fit reconditioned valve bore.

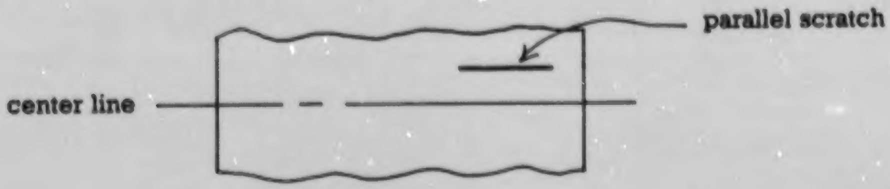
2. Spools can be plated to increase their size if a new spool cannot be purchased. This is seldom done because of cost.

C. Defects

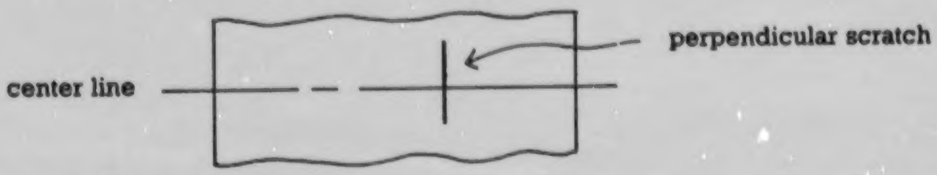
1. Small nicks, burrs, and other defects should be stoned out until a smooth surface is obtained. Care must be taken so spool is not damaged (ex. flat spot stoned into valve spool).

2. Large defects - replace.

3. In most cases, scratches that are parallel to spool center line will cause leakage.



4. Scratches perpendicular to center line will normally not cause many problems if they are smoothed out.



VI. Body bore repair

A. Tools

1. Round cross section stones should be used inside bore to stone out scratches. Any other shape will present a sharp edge to the bore.

2. Use a red india type stone for burr and nick removal.

3. Use an Arkansas hard white stone to remove fine scratches and to polish out marks left by the red india type stone.

4. Bores can be honed to produce a uniform diameter and finish.

B. Special consideration - Some valves have been manufactured with bores that have been hardened by roller burnishing or other methods. This surface hardness is only .0002 - .0004 inches thick. If this hardened surface is removed rapid valve wear will result.

C. Size - It is not practical to repair bodies if they have excessive wear, or have been damaged severely.

1. Normally a worn body is discarded and a new one is purchased.

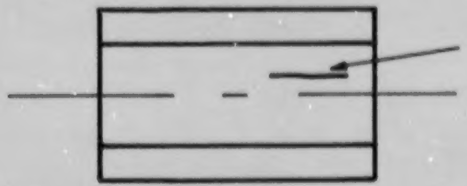
2. Bodies can be plated to decrease size if a new one cannot be purchased. This is seldom done because of cost.

D. Defects

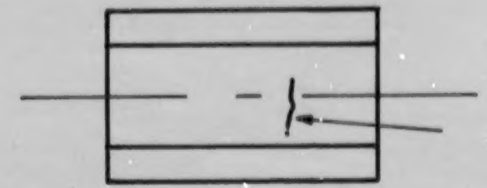
1. Small nicks, burrs, and other defects should be stoned out until a smooth surface is obtained. Care must be exercised so bore is not damaged. (Example - Flat spot stoned in valve body bore.)

2. Large defects - replace.

3. In most cases, scratches that are parallel to bore center line will cause leakage.



4. Scratches perpendicular to center line of bore will normally not cause leakage problems as long as they are stoned out.



VII. Measuring piston joint end play - This method is used to determine the amount of end play in the ball and socket joint of a piston on a pump or fluid motor.

A. Clean part with an approved solvent.

B. Wipe clean with a lint free paper towel.

C. Inspect ends of part (piston and shoe) for, and remove, small burrs and nicks by stoning with a red india type stone.

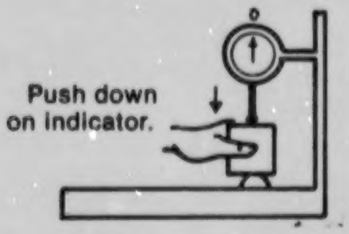
D. Clean and wipe dry again if part was stoned.

E. Measure part.

1. Clean surface plate and indicator stand.

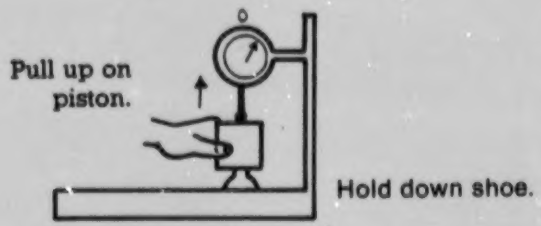
2. Mount a 0.001 inch division dial indicator on stand.

3. Place piston on surface plate under indicator point and push piston down removing clearance in ball socket joint. Note - Piston spool should be perpendicular to surface plate.



4. Zero indicator dial.

5. Hold piston against surface plate with one hand and pull up on piston with the other.



6. Record dial indicator reading.

F. Repeat for each piston/shoe assembly.

1. Allowable end play - Consult manufacturer's catalog for maximum allowable end play; if not available, use 0.006 inch maximum.

2. If one piston is found to be defective replace entire set.

G. Calculate out of roundness.

Out of roundness = Largest value - Smallest value at a location

Record out of roundness at each location.

O.R. @ 1 ________ O.R. @ 2 ________ O.R. @ 3 ________

(Note - This procedure can be used to measure piston pump piston bores.)

VIII. Measuring flatness of parts

Note - This method can be used to check flatness of parts when both sides of part have been machined parallel to one another. This method is more accurate than using a straight edge and looking for light indication between part and straight edge because the actual measurement can be determined.

A. Clean part with an approved solvent.

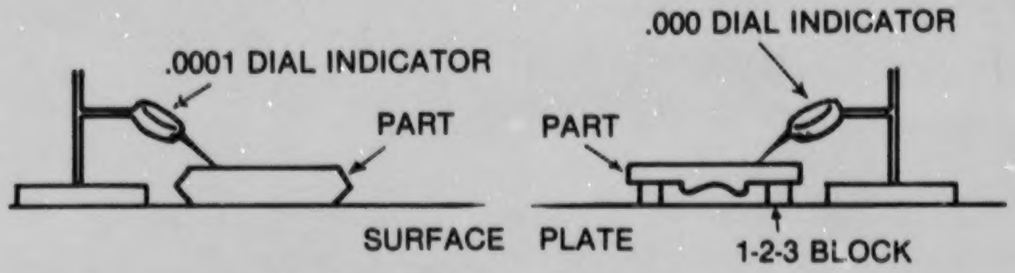
B. Wipe clean with a lint free paper towel.

C. Inspect part for, and remove, any small burrs or nicks by stoning with a red india type stone.

D. Clean and wipe dry again if part was stoned.

E. Clean surface plate, indicator stand, and 1-2-3 gage blocks (if required).

F. Place part on surface plate using gage blocks if required.



G. Mount a 0.0001 inch division dial indicator on indicator stand.

H. Zero indicator at low point on part, move to high point and record reading

or

Record lowest and highest reading, subtract low from high reading and record.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 3: CHECKING TOLERANCE ON PARTS

Interaction Items: (Review Items)

1. How does diametrical clearance affect oil leak rate?
2. Discuss the cost of rebuilding parts as compared to buying new ones.
3. Discuss how small 0.001 inch and 0.0001 inch are.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 3: CHECKING TOLERANCE ON PARTS

Evaluation Items:

1. How should parts be cleaned before checking tolerances?

   a.

   b.

   c.

   d.

   e.

2.1 How should a valve spool be measured?

   a.

   b.

   c.

   d.

2.2 How should a valve spool be checked for camber?

   a.

   b.

   c.

   d.

   e.

3. How should a valve body bore be measured?

   a.

   b.

4. How is spool to body bore diametrical clearance calculated?

5. Discuss spool repair.

6. Discuss body bore repair.

7. How is piston joint end play measured?

8. How is a part measured for flatness?

    a.

    b.

    c.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 3: CHECKING TOLERANCE ON PARTS

Answers to Evaluation Items:

1. a. Clean part with approved solvent.
   b. Wipe dry with a lint free paper towel.
   c. Inspect part for and remove small burrs.
   d. Clean and wipe dry again if part had to be stoned.

2.1 a. Let part temperature stabilize to 60° - 72°F.
   b. Use a vernier micrometer.
   c. Check calibration of micrometer.
   d. Measure part diameter at 9 locations, record findings. Average diameter at each location.
   e. Calculate out of roundess and record findings.

2.2 a. Clean surface plate, indicator stand and V-blocks.
   b. Place valve spool on V-blocks.
   c. Mount a 0.001 with division dial indicator on dial stand.
   d. Zero indicator on end of spool.
   e. Pass indicator over the center of spool valve; record reading.

3. a. Let part temperature stabilize to 68 - 72°F.
   b. Measure parts.

      1) Use a vernier micrometer.
      2) Check calibration of micrometer.
      3) For transfer gages use:

         a) Inside micrometer or
         b) Telescoping gage or
         c) Small hole gage on small valves (ball or sliding wedge type)

      4) Take measurements and record reading.

4. D.C. = Average Maximum Bore Diameter - Average Minimum Spool Diameter

5. Discussion should include a comment on each of the major points in section V.

6. Discussion should include a comment on each of the major points in section VI.

7. a. Clean surface plate and indicator stand.
   b. Mount a 0.001 inch division dial indicator on stand.
   c. Place piston on surface plate under indicator point and push piston down removing clearance in ball socket joint.
   d. Zero indicator dial.

e. Hold piston shoe against surface plate with one hand and pull up on piston with the other.
f. Record dial indicator reading.

8. a. Place part on suface plate using gage blocks if required.
b. Mount a 0.0001 inch division dial indicator on indicator stand.
c. Zero indicator at low point on part, move to high point and record reading, or record lowest and highest reading, subtract low from high reading and record.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

Scope of Unit: After completion of this unit the student will be familiar with the correct test procedures to inspect components and component parts for reuse, and for documentation of the parts. The student should be able to discuss these procedures and score 85% on the evaluation items.

LESSON 4: QUALIFY PARTS FOR REUSE

Lesson Objectives - the student should be able to:

1. List the information which must be checked before repair of a component is undertaken.

2.1 List reasons why seals should not be reused.

2.2 State six items which should be checked and corrected, if defective, when replacing seals.

2.3 List four rules that apply when working with seals.

3. Discuss inspection of a flat face sealing surface.

4. Discuss inspection of O-ring face seals.

5. Describe the inspection and methods of correcting defects in the parts of a directional control valve.

6. Discuss the items to be checked when inspecting a gear, vane, or piston pump.

7. Recall the items to check and steps to correct defects when inspecting a hydraulic cylinder.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: Qualifying parts for reuse is based on two major factors: test results and good judgment. Of the two, good judgment is the more important factor.

LESSON 4: QUALIFY PARTS FOR REUSE

Outline: (Key Points)

I. Information: Before a component is disassembled, consult maintenance manuals and parts breakdown sheets to:

  A. Note special warnings or disassembly instructions.

  B. See if special tools are required.

  C. Check for listing of any part(s) which must be replaced just because component is taken apart.

II. Seals

  A. Seals should not be reused, unless there is a special reason to do so.

    1. Seals can take a permanent set.

    2. Small defects that are not noticeable when seal is loose can cause problems at installation.

    3. Seals can crack from age.

    4. Seals can become contaminated with abrasives, leading to accelerated wear.

  B. When replacing seals on any hydraulic equipment or component, check seals for the following:

    1. Correct size

    2. Cleanliness of seal and sealing surface

    3. Compatability with the fluid being used

    4. Compatability with the fluid operating temperature

    5. Are backup ring(s) or special seal supports required at installation?

    6. Amount (if any) of precompression required to set seal

  C. Because seals are relatively delicate and easily contaminated, the following rules apply when working with seals:

    1. Leave in protective packaging to keep clean until needed.

2. Inspect before use.

3. Lubricate (with clean system fluid) before installing.

4. Use utmost caution to prevent damage when installing.

III. Flat face sealing surfaces:

A. Before a sealing surface can be inspected it must be cleaned.

1. Wash with an approved solvent - Do not under any circumstances scrape surface with any metal object. If surface must be scraped use a piece of soft wood, i.e., white pine.

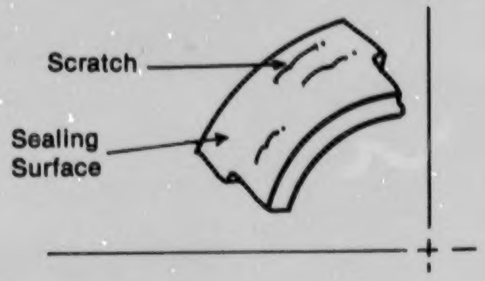
2. Wipe clean with a clean lint free paper towel.

B. Once the sealing surfaces have been cleaned, they can be inspected for the following:

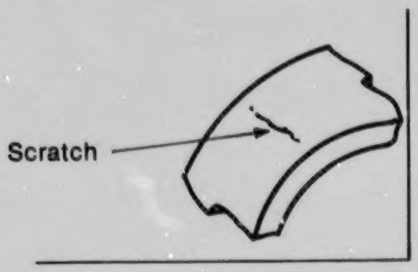
1. Flatness - This check can usually be done by holding the part up to a light source and laying a straight edge across the face to see if any light shines through.

2. Scratches, burrs, and nicks

a. Parallel to sealing surface: These usually cause no problem as long as any sharp edge or protrusion above the surface can be stoned away, and sharp edges rounded using number 400 emery cloth.



b. Perpendicular to sealing surface - Any deep scratch or nick running across the sealing surface is cause to reject the part for reuse. Light scratches or nicks can be stoned and polished out.

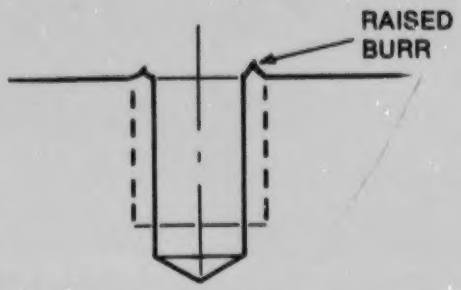


3. Pulled threads on seal surface - Check for raised burrs at tapped holes, if present.

    a. Countersink hole with scraper.

    b. Lightly stone surface to remove small upsets in metal.

    c. Retap if required.



IV. O-ring face seals, gland, and reciprocating seals

A. O-ring face seals

(Note - Clean sealing surfaces before inspection as described in section III. Once the sealing surfaces have been cleaned, they can be inspected for scratches, burrs, and nicks.)

1. Parallel to groove - This type of damage usually will not cause problems as long as sharp edges are removed. To remove these edges, use emery paper or valve grinding compound and a wood form to lap surface.

2. Perpendicular - These can cause problems so they must be removed by stoning or the use of valve grinding compound.

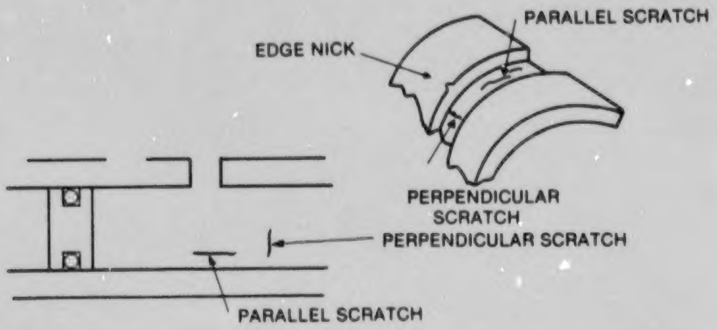
3. Edge nick - Nicks on the edge can cause O-ring extrusion.

    a. If backup ring is used, just stone out nick.

    b. If no backup ring is used,

        1) Stone out very small nicks.

        2) Large nicks usually mean that the part must be scrapped, unless nick can be filled.



B. O-ring, gland, and reciprocating seals

1. Parallel scratch - This type of defect can cut O-rings, causing a leak path. Parallel scratches should be removed by stoning or honing the bore. If deep, the bore may have to be plated and honed to bring it back into tolerance. Correct

bore tolerance can be determined by the use of an O-ring handbook whick lists tolerance for each O-ring size and original equipment manufacturer's reference material.

2. Perpendicular scratch - Lightly stone to remove sharp edges and to radius corners.

BEFORE
AFTER

3. Intersecting holes - Stone away sharp edge and radius corner.

V. Pressure and Directional Control Valves - The following items should be inspected on a valve before reassembly.

A. Valve operators or solenoid coils - Check for correct operation. Discard coils if found open on continuity check.

B. Springs - Replace if broken.

C. Poppet (dart) seats - Lap poppet to seat with lapping compound if seat contains scratches. If this is done, take care to thoroughly clean valve, with an approved solvent, to remove all traces of lapping compound.

D. Sealing sufaces - inspect and repair if necessary (and possible) using methods described in sections III and IV.

E. Inspect bore of valve body for defects - Repair if necessary (and possible) using method(s) described in Unit III, Lesson 3.

F. Inspect spool for defects, repair if necessary (and possible) using method(s) described in Unit III, Lesson 3.

G. Check metal spool to metal body fit - See Unit III, Lesson 3.

H. Seals - See section II.

I. Gaskets - Inspect gaskets on electrical enclosure and solenoid(s). Replace if torn or excessively flattened.

J. Threads, fasteners, and pipe connections

1. Clean out old thread sealant and any anti-vibration compound that was used.

2. Retap hole(s) if required.

3. Replace worn or stripped threaded fasteners.

K. Snap rings and retainer rings - Inspect and replace as required.

L. Spring pins - Replace if removed from assembly.

VI. Inspection of gear, vane, or piston pumps

A. Gear type pumps and fluid motors - The following items should be inspected before reassembly of component.

1. Inspect roller and needle bearings for:

    a. Signs of face wear due to fatigue, corrosion, spalling, or brinelling

    b. Pitting, flacking or chipping of needle and balls

    c. Excessive internal radial and end play

    d. Correct fit on shaft

    e. Correct fit in housing

    f. Correct amount of end play when assembled on shaft in housing

    (Note - Replace if any of the above items are found to be out of spec.)

2. Inspect shaft for wear at seals. Replace shaft or have plated and ground if excessive wear is present.

3. Springs - Replace if broken.

4. Inspect sealing surfaces. Repair if necessary (and possible) using methods described in sections III and IV.

5. Seals - See section II.

6. Keyways and splines - Lightly stone using red india type stone to remove any burrs or small nicks then inspect for fit with mating part(s) for:

    a. Rocking - side to side play

    b. Sliding or press fit on shaft, as required

7. Snap rings and retainer rings - Inspect and replace as required.

8. Gears and pump housing

    a. Inspect gears for excessive wear on teeth. Replace if necessary.

    b. Inspect bore of pump body for scratches. Lightly stone rough edges.

    c. Inspect bore to gear running clearance. If more than 0.0005 inch consider replacing body and gears. To be sure, a volumetric efficiency test on assembled pump can be performed.

9. End plates - Should be inspected for wear and scratches. If more than 0.002 inches deep, replace. If less, lap and polish out.

10. Inspect internal relief valve (if so equipped).

    a. Poppet seat - Lap to remove wear marks if required. Clean thoroughly afterwards.

    b. Check spring and adjust screw.

11. Threads, fasteners, and pipe connections

    a. Clean out old thread sealant and any anti-vibration compound that was used.

    b. Retap hole(s) if required.

    c. Replace worn or stripped threaded fasteners.

B. Vane type pumps and fluid motor - The following items should be inspected before reassembly of unit.

1. Inspect roller and needle bearings for:

    a. Signs of face wear due to fatigue, corrosion, spalling, or brinelling

    b. Pitting, flacking or chipping of needle balls

    c. Excessive internal radial and end play

    d. Correct fit on shaft

    e. Correct fit in housing

    f. Correct amount of end play when assembled on shaft in housing

    (Note - Replace if any of the above items are found to be out of spec.)

2. Inspect shaft for wear at seals. Replace shaft or have plated and ground if excessive wear is present.

3. Springs - Replace if broken.

4. Inspect sealing surfaces. Repair if necessary (and possible) using methods described in sections III and IV.

5. Seals - See section II.

6. Keyways and splines - Lightly stone using red india type stone to remove any burrs or small nicks then inspect for fit

with mating part(s) for:

a. Rocking - side to side play

b. Sliding or press fit on shaft, as required

7. Snap rings and retainer rings - Inspect and replace as required.

8. Vanes - Inspect for:

   a. Fit in rotor - If there is not a smooth sliding fit without any noticeable side play, replace the vane.

   b. Edge of vane - If thin or shows excessive wear, replace.

   c. Any signs of cracking in vanes, replace.

9. Rotor ring - Inspect bore for:

   a. Scratches - Polish out if required.

   b. Ridges - Polish out if required.

   c. Humps formed from vane hopping - Polish out if required.

   If any of the above is more than 0.001 inch deep, consider replacing (if necessary). Confirm by running volumetric efficiency test on assembled unit.

10. Rotor

    a. Lightly stone any sharp edges on vane slots.

    b. Lightly stone and lap ends if required. No more than 0.002 should have to be removed; if so, replace.

11. Valve/port plate - Inspect for wear and scratches.

    a. Lightly lap to remove scratches.

    b. Remove no more than 0.0004 inch; if more, replace.

    c. Check for flatness; if out more than 0.0005 inch, replace.

12. Threads, fasteners, and pipe connections

    a. Clean out old thread sealant and any anti-vibration compound that was used.

    b. Retap hole(s) if required.

    c. Replace worn or stripped threaded fasteners.

C. Piston pumps

1. Inspect roller and needle bearings for:

   a. Signs of face wear due to fatigue, corrosion, spalling, or brinelling

   b. Pitting, flacking or chipping of needle balls

   c. Excessive internal radial and end play

   d. Correct fit on shaft

   e. Correct fit in housing

   f. Correct amount of end play when assembled on shaft in housing

   (Note - Replace if any of the above items are found to be out of spec.)

2. Inspect shaft for wear at seals. Replace shaft or have plated and ground if excessive wear is present.

3. Springs - Replace if broken.

4. Inspect sealing surfaces. Repair if necessary (and possible) using methods described in sections III and IV.

5. Seals - See section II.

6. Keyways and splines - Lightly stone using red india type stone to remove any burrs or small nicks then inspect for fit with mating part(s) for:

   a. Rocking - side to side play

   b. Sliding or press fit on shaft, as required

7. Snap rings and retainer rings - Inspect and replace as required.

8. Valve/port Plate - Inspect the flat surface that mates with the cylinder barrel.

   a. Lightly stone out small scratches on the surface.

   b. Replace if more than 0.0004 inch has to be removed to clean up surface.

   c. Check for flatness; if out more than 0.0005 inch, replace.

9. Cylinder barrel - Inspect the following:

   a. Piston bore:

    1) Look for scratches; if excessive, replace barrel.

    2) Remove lip that may have formed at end of bore by lightly stoning.

  b. Running face - Inspect the running face that contacts the valve plate.

    a) Lap or stone out small defects.

    b) If more than 0.0004 inch has to be removed for complete clean up by hand methods, replace or see step 3.

    c) The barrel running face can be surface ground and lapped to restore to like-new condition if not more than 0.010 inch of material is removed.

10. Pistons - Inspect for the following defects.

    (Note - If a defect is found on one piston in the set, replace the entire set, not just one.)

    a. Inspect piston surface for scratches. If they can be felt with fingernail, replace.

    b. Check fit in piston barrel. If side play can be detected, replace set.

    c. Measure shoe end play. If in excess of 0.005 inch, replace set. See method used in Unit III, Lesson 3.

    d. Inspect shoe face for scratches. Lightly stone to remove. If more than 0.001 inch, replace set.

    e. Inspect shoe face for nicks. If there are any, replace set.

    f. Measure shoe face thickness. All piston shoe faces should be within 0.001 inch; if not, replace set.

11. Inspect the swash plate.

    a. Stone the swash plate lightly to remove minor defects.

    b. If more than 0.0004 inches has to be removed, replace.

    c. Check for flatness. If out more than 0.0005 inch, replace.

12. Threads

    a. Clean out old thread sealant tape and any anti-vibration compound that was used.

    b. Retap hole(s) if required.

c. Replace worn or stripped threaded fasteners.

VII. Cylinders - Inspect for the following defects:

A. Threads

1. Clean out old thread sealant and any anti-vibration compound that was used.

2. Retap hole(s) if required.

3. Replace worn or stripped threaded fasteners.

B. Seals - See section II.

C. Rod cartridge:

1. Inspect sealing surfaces. See sections III and IV for details.

2. Measure bearing for fit with rod; if more than 0.0020 inch diametrical clearance, replace.

3. Remove light scratches and nicks by honing bore.

D. Tube end sealing surfaces in end caps - Inspect and repair if necessary per section IV.

E. Tube end sealing surfaces - Inspect and repair if necessary per section III.

F. Tube bore - Inspect for:

1. Bore defects - Hone to remove slight defects.

2. Large bore defects - replace.

3. Dented tube bore - replace.

G. Piston

1. Outside diameter - lightly stone to remove small defects.

2. Inspect sealing grooves per section IV.

3. Check rod to piston connection. If damaged, replace. See manufacturer's special procedures.

H. Piston rod - inspect.

1. Size - If not uniform within 0.001 inch, replace.

2. Scratches and nicks - Stone out defects, if small.

3. Pitting - Replace rod or replate and grind.

I. Internal cushions, valves, etc. - Inspect per section V.

J. Mounting attachments, pins, etc.

  1. Visual inspection on fits
  2. Dye penetrant check for stress cracks
  3. Check for bending in pins

LESSON 4: QUALIFY PARTS FOR REUSE

Interaction Items: (Review Items)

1. Discuss cost of repairing a part versus buying a new one.
2. Discuss cleaning of parts.
3. Show samples of parts that are worn.
4. Demonstrate the inspection of bearings.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 4: QUALIFY PARTS FOR REUSE

Evaluation Items:

1. Before a repair, what should be checked?

   a.

   b.

   c.

2.1 Why should seals not be reused?

   a.

   b.

   c.

   d.

2.2 When replacing seals, what items should be checked?

   a.

   b.

   c.

   d.

   e.

   f.

2.3 List rules that apply when working with seals.

   a.

   b.

   c.

   d.

3. Discuss inspection of flat face sealing surface.

4. Discuss inspection of O-ring face seals.

5. Write a comment about each of the topics listed below on inspection of parts for a directional control valve.

   a. Valve operators

   b. Springs

   c. Poppet seats

   d. Sealing surfaces

   e. Valve body bore

   f. Spool inspection

   g. Check fit of spool to body.

   h. Seals

   i. Gaskets

   j. Threads

6. Discuss the inspection of either a gear, vane or piston pump.

7. Discuss the inspection of a hydraulic cylinder.

LESSON 4: QUALIFY PARTS FOR REUSE

Answers to Evaluation Items:

1. a. Special warning
   b. If special tools are required
   c. What parts must be replaced because component is just disassembled

2.1 a. Permanent set
    b. Small unseen defects
    c. Age cracking
    d. Contamination

2.2 a. Size
    b. Cleanliness
    c. Compatability with fluid
    d. Compatability with temperature
    e. Required backup ring
    f. Amount of precompression

2.3 a. Keep clean.
    b. Inspect.
    c. Lubricate before installing.
    d. Use care when installing.

3. Discussion should include a check for flatness and comments on defect removal by stoning.

4. Discussion should include a reference to repair of defects in parallel and perpendicular direction and what to do with nicks.

5. Answers should contain information listed in section V.

6. Discussion should include a comment on each item to be checked. Answer should contain information from section VI., for the item chosen by the student.

7. Answer should contain information in section VII.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

Scope of the Unit: After completion of this unit the student will be familiar with the correct test procedures to inspect components and component parts for reuse, and/or documentation of the parts. The student should be able to discuss these procedures and score 85% on the evaluation.

LESSON 5: DISASSEMBLE, INSPECT, AND REASSEMBLE A DIRECTIONAL CONTROL VALVE (DEMONSTRATION LESSON)

Lesson Objectives - the student should be able to:

1. Disassemble a directional control valve.
2. Clean parts.
3. Inspect and qualify parts for reuse.
4. Reassemble a directional control valve.
5. Test the unit.
6. Document work.

Supplementary Teaching/Learning Items:

1. Service manual for valve being measured.

Informational Assignment: (Student)

Review and study Unit 3, Lessons 3 and 4.

References: (Instructor's Additional Information)

Service and part manual on valve being used.

Introduction: There are many different types of valves but most are similar in design. The techniques used here can be applied to most spool type valves.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 5: DISASSEMBLE, INSPECT, AND REASSEMBLE A DIRECTIONAL CONTROL VALVE

Tools, Equipment, and Materials:

Directional control valve (NOTE: This procedure assumes that a manually operated directional control valve will be used. Other types of directional control valves may be used with minor changes to this procedure.)
Service manual if available
Hand tools
Lint free paper towels
Shipping plugs for open ports
Safety glasses
Surface plate
V-blocks
0.0001 inch division dial indicator
0-1 inch - 0.0001 inch division micrometer
Telescope gage of bore size of valve
Indicator stand

Steps of Procedure: (Job Sheet)

I. Disassemble a directional control valve.

(Note - Be sure spools are replaced into the openings from which they were removed. To prevent thermal expansion, avoid handling for a long period of time).

A. Install the shipping plugs into the valve ports.

B. Clean the external surfaces of the valve with solvent.

C. Place the valve in a clean area for disassembly.

D. Remove the spool handle if not already removed.

E. Remove the end cap.

F. Remove the nut that holds the centering spring and remove spring.

G. Carefully slide the spool from the valve body.

II. Clean all parts per instructions in Unit 3, Lessons 3 and 4.

III. Inspect a directional control valve.

(Note - After completing each item in the inspection list, check the appropriate box and comment on the condition of work performed.)

Note - Numbers in parentheses refer to the information lesson in which this topic is discussed.

	Part		Comments
	OK	Replace	
A. Inspect subplate sealing surface (3-4)			
B. Check valve operators (3-4)			
C. Springs (3-4)			
D. Sealing surfaces (3-4)			
E. Inspect valve body bore for defects (3-3, 3-4)			
F. Measure valve body bore (3-3)			

1	2	3
A ____________	A ____________	A ____________
B ____________	B ____________	B ____________
C ____________	C ____________	C ____________
Avg ____________	Avg ____________	Avg ____________

G. Inspect valve spool for defects (3-3, 3-4)

H. Measure valve spool (3-3)

1	2	3
A ____________	A ____________	A ____________
B ____________	B ____________	B ____________
C ____________	C ____________	C ____________
Avg ____________	Avg ____________	Avg ____________

I. Calculate diametrical clearance (3-3).

D.C. = ______________

J. Inspect seals (3-4); Do not replace for this exercise unless damaged

K. Inspect gaskets (3-4).

L. Inspect threads (3-4).

	Part		Comments
	OK	Replace	
M. Inspect snap ring (if any) (3-4).			
N. Inspect spring pins (if any) (3-4).			
IV. Reassemble a directional control valve (Note - Lubricate all components during reassembly) A. Carefully install the spool into the valve body, and use special care to insure that the O-rings are not damaged during installation.			
B. Install the centering spring and washers (if used) and retaining nut.			
C. Tighten nut.			
D. Install end cap.			
E. Install spool handle.			

V. Test unit	Acceptable	Not Acceptable
Does valve operate correctly?	____	____
Check valve leakage.	____	____

VI. Documentation - Check off as completed.

A. Service manuals returned _____

B. Lubrication schedule updated _____

C. Preventive maintenance schedule updated _____

D. Spare parts inventory checked _____

E. Spare parts list made up and attached _____

F. Machinery file updated _____

Interaction Items: (Review Items)

1. What were the results of inspection?
2. What is the condition of the valve?

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 5: DISASSEMBLE, INSPECT, AND REASSEMBLE A DIRECTIONAL CONTROL VALVE

Evaluation Items:

The student has satisfactorily completed the following steps of procedure:

I. Disassembled a directional control valve.
II. Cleaned parts.
III. Inspected and qualified parts for reuse or replacement.
IV. Reassembled a directional control valve.
V. Tested the unit.
VI. Documented work.

Yes __________ No __________

____
Instructor's Signature
(Verifying Satisfactory Completion)

Date: __________________________

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

Scope of the Unit: After completion of this unit the student will be familiar with the correct test procedures to inspect components and component parts for reuse, and for documentation of the parts. The student should be able to discuss these procedures and score 85% on the evaluation.

LESSON [illegible] DISASSEMBLE, INSPECT, AND REASSEMBLE A PRESSURE COMPENSATED VARIABLE VOLUME PUMP (DEMONSTRATION LESSON)

Lesson Objectives - the student should be able to:

1. Disassemble a pressure compensated, variable volume pump.
2. Inspect and qualify parts for reuse.
3. Reassemble the pump.
4. Test.
5. Document work.

Supplementary Teaching/Learning Items:

1. Transparency master of pump and parts to be used in demonstration.
2. Service manual and material for pump being used.

Informational Assignment: (Student)

Review and study Unit 3, Lessons 3 and 4.

References: (Instructor's Additional Information)

Service and parts manual on pump being used

Introduction: This Demonstration Lesson should be undertaken as if you had to decide what to do with the pump - repair or buy new.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 6: DISASSEMBLE, INSPECT, AND REASSEMBLE A PRESSURE COMPENSATED VARIABLE VOLUME PUMP

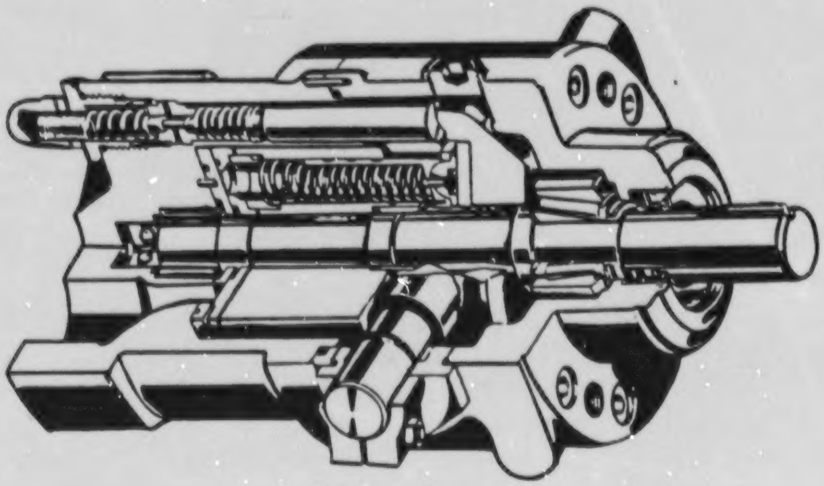
Tools, Equipment, and Materials:

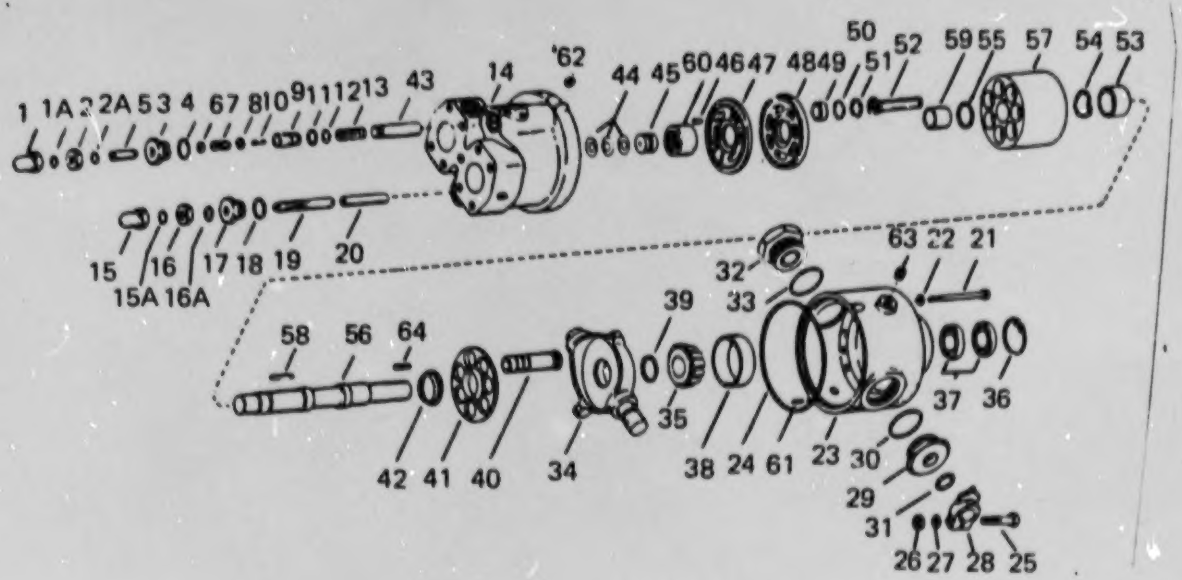
Pressure compensated pump
    (Note - This job sheet assumes that an in-line axial piston pump will be used. The procedures are similar for other types of pressure compensated pumps.)
Service manual for pump
Hand tool set
Solvent
Lint free paper towels
Safety glasses
Surface plate
0.1 inch - 0.0001 division micrometer
Dial indicator
Indicator stand
Telescope gage of bore size of piston

Steps of procedure: (Job Sheet)

(Note - The procedures here assume a pressure compensated in-line axial piston pump. A cut-away view of such a pump is shown in Figure 1. An exploded view of this pump is shown in Figure 2.)

Figure 1




1
1A
2
2A
5
3
4
6
7
8
10
9
11
12
13
43
14
62
44
45
60
46
47
48
49
50
51
52
59
55
57
54
53
15
15A
16
16A
17
18
19
20
32
33
63
22
21
39
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56
64
37
36
35
42
41
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61
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29
31
26
27
28
25

No.	Description	Qty.
1	Acorn nut	1
1A	Packing, preformed	1
2	Jam nut	1
2A	Packing, preformed	1
3	Adjustment plug	1
4	Preformed packing	1
5	Adjustment screw	1
6	Spring seat	1
7	Compensator spring	1
8	Spring seat	1
9	Compensator shell	1
10	Compensator piston	1
11	Quad ring	1
12	Quad ring	1
13	Starting spring	1
14	Control piston	1
15	Acorn nut	1
15A	Packing, preformed	1
16	Jam nut	1
16A	Packing, preformed	1
17	Adjustment plug	1
18	Preformed packing	1
19	Adjustment screw	1
20	Control piston	1
21	Cap screw	8
22	Washer	8
23	Drive cover	1
24	Preformed packing	1
25	Cap screw	1
26	Nut	1
27	Lockwasher	1
28	Indicator	1
29	Thru trunnion nut	1
30	Preformed packing	1
31	Preformed packing	
32	Blind trunnion nut	
33	Preformed packing	1
34	Reaction swivel assy	1
35	Bearing	1
36	Snapring	1
37	Seal	2
38	Bearing cup	1
39	Thrust washer	1
40	Piston assembly	7
41	Holddown plate	1
42	Ball bushing	1
43	Port end cover	1
44	Spring	3
45	Bearing	1
46	Dowel	1
47	Fixed port plate	1
48	Rotating port plate	1
49	Cylinder seal	7
50	Preformed packing	7
51	Washer	7
52	Spring	7
53	Spring sleeve	1
54	Wave washer	3
55	Snapring	1
56	Drive shaft	1
57	Rotor	1
58	Key	1
59	Bearing race	1
60	Bearing	1
61	Case dowel	1
62	Pipe plug	1
63	Pipe plug	1
64	Key	1

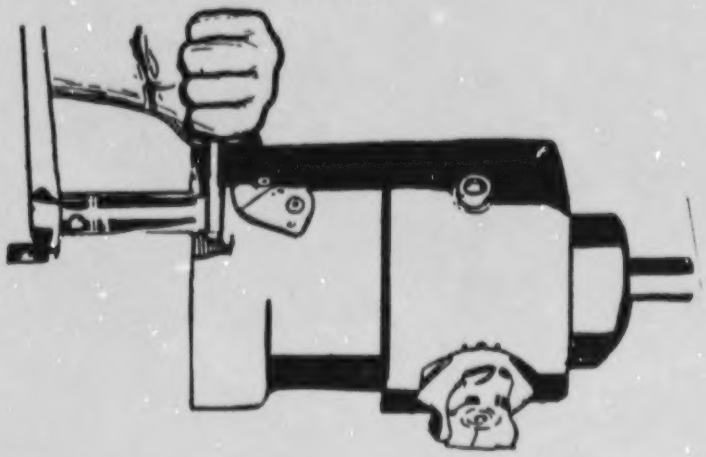
I. Disassemble

   A. Clean the external surfaces of the pump, using solvent to remove all dirt and grime.

   B. Dry pump with paper towels.

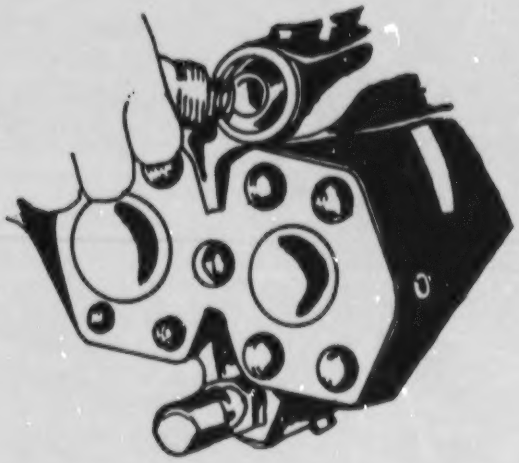
   C. Loosen the jam nut and unscrew the compensator adjustment screw (Figure 3).

Figure 3



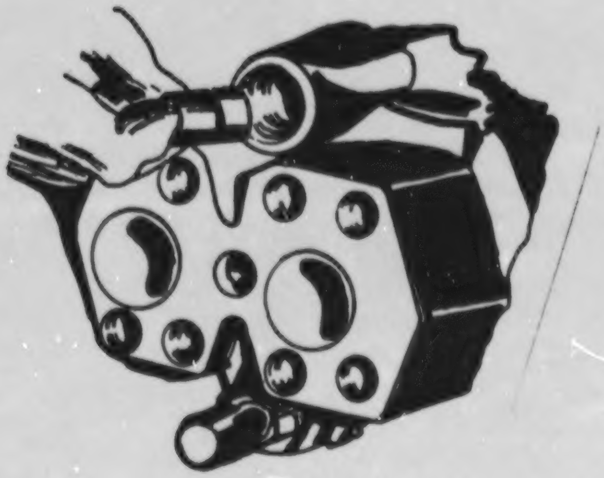
   D. Remove the compensator spring seat and compensator spring (Figure 4).

Figure 4



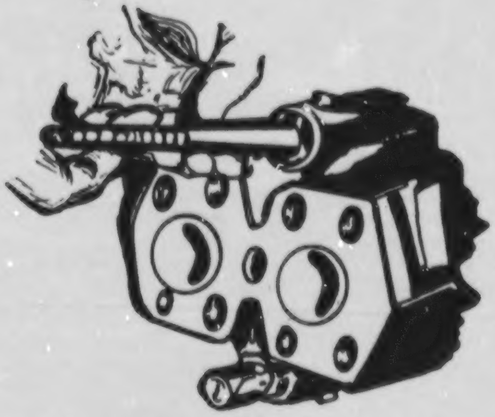
E. Remove the compensator spool (Figure 5).

Figure 5



F. Remove the compensator piston and spring (Figure 6).

Figure 6



G. Remove the retaining nut for the compensator piston on the other side of the pump.

H. Remove the spring and piston.

I. Unscrew the cap screws that hold the pump housing together (Figure 7).

(Note - Be careful to lift the cover straight up. Be especially careful to insure that the pistons are free of the swash plate.) (Figure 8)

Figure 7

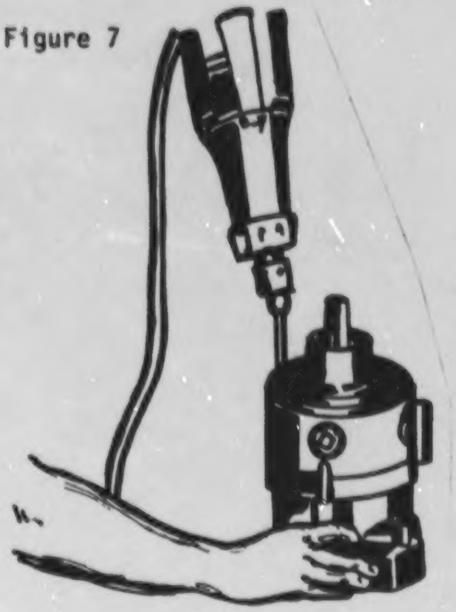
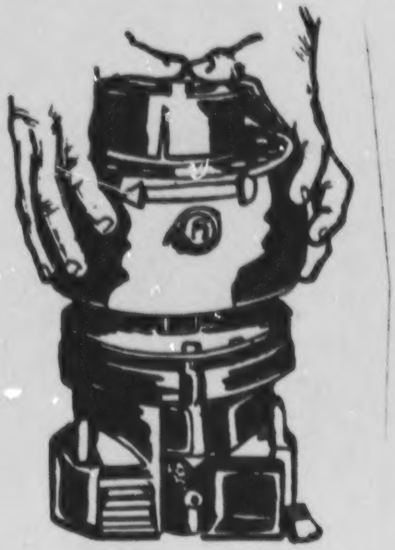
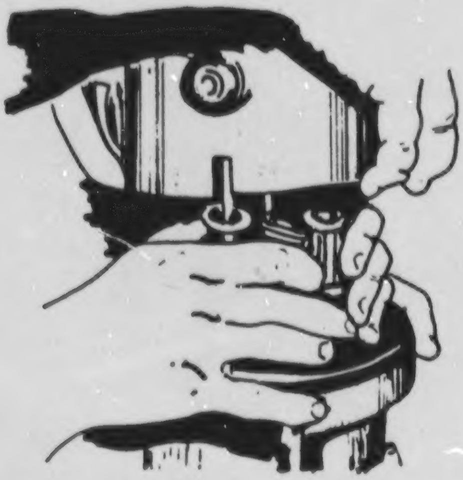


Figure 8



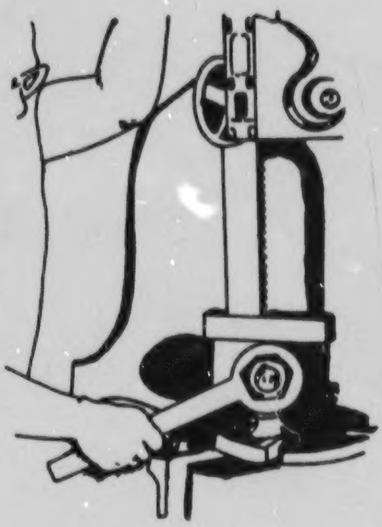
J. Carefully remove the drive end cover from the port end cover (Figure 9).

Figure 9



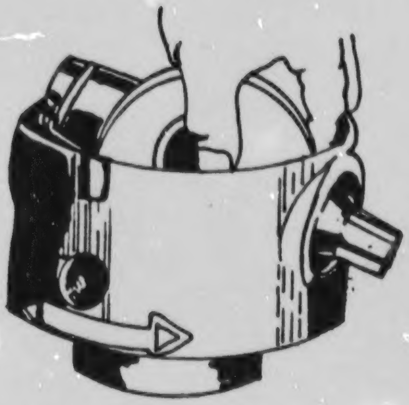
K. Remove the pistons from the assembly (Figure 10).

Figure 10



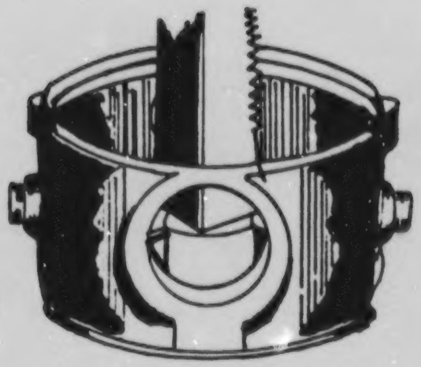
L. Remove the port end cover from the barrel and shaft assembly (Figure 11).

Figure 11



M. Remove the port plate from the port end cover (Figure 12).

Figure 12



II. Inspect pump

Notes - Clean all parts per instructions in Unit 3, Lessons 3 and 4.

After completing each item in the inspection list, check the appropriate box and comment on condition of work performed.

Numbers in parentheses refer to lesson in which this information is presented.

	Part		Comment
	OK	Replace	
A. Inspect bearing (3-4).			
B. Inspect shaft (3-4).			
C. Inspect spring (3-4).			
D. Inspect sealing surfaces (3-4).			

	Part		Comment
	OK	Replace	
E. Inspect seals (3-4); Do not replace in this exercise unless damaged.			
F. Inspect keyways and splines (3-4).			
G. Inspect snap ring and retainer ring (3-4).			
H. Inspect valve plate (3-3, 3-4).			
I. Inspect cylinder barrel running face (3-3, 3-4).			
J. Inspect piston bore (3-3, 3-4).			
K. Measure piston to piston bore fits (3-3).			
L. Inspect piston surface (3-3, 3-4).			
M. Inspect piston end play (3-3, 3-4).			
N. Inspect piston shoe face (3-4).			
O. Measure piston shoe thickness (3-3).			
P. Inspect swash plate (3-3, 3-4).			
Q. Inspect thread (3-4).			
R. Inspect compensator.			

III. Reassemble

A. Install the port plate into the port end housing.

B. Place the cylinder barrel and shaft assembly into the port end housing.

C. Install the pistons into the assembly.

D. Install the bearing, seal, and seal-retainer ring into the shaft end cover.

E. Install the swash plate into the shaft end cover.

F. Install the trunnion nut to secure the swash plate.

G. With the port end cover lying on a flat surface with the ports down, carefully lower the shaft end cover onto the assembly.

H. Make sure that the piston shoes properly contact the swash plate.

I. Install the cap screws to secure the two halves of the pump assembly.

J. Torque the screws to manufacturer's recommended specifications by tightening screws on opposite sides of the pump in sequence.

K. Install the lower piston with spring and tighten screw cap.

L. Install the upper piston with spring, compensator spool, spool spring, and adjustment screw.

M. Tighten adjustment screw only partially into the pump.

IV. Test unit

	Manufacturer's data	Test data
Speed	________	________
Flow-pump output	________	________
Flow-case drain	x	________
Volumetric EFF	________	________
Leaks at joints	x	________

Pump operates (check one) Correctly ________

Incorrectly ______

V. Documentation - Check off as completed.

A. Service manuals returned ____

B. Lubrication schedule updated ____

C. Preventive maintenance schedule updated ____

D. Spare parts inventory checked ____

E. Spare parts list made up and attached ____

F. Machinery file updated ____

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 6: DISASSEMBLE, INSPECT, AND REASSEMBLE A PRESSURE COMPENSATED VARIABLE VOLUME PUMP

Interaction Items: (Review Items)

1. What did inspection reveal and what is the condition of the pump?

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 6: DISASSEMBLE, INSPECT, AND REASSEMBLE A PRESSURE COMPENSATED VARIABLE VOLUME PUMP

Evaluation Items:

The student has satisfactorily completed the following steps of procedure:

I. Disassembled a pressure compensated, variable volume pump.

II. Inspected and qualified parts for reuse or replacement.

III. Reassembled the pump.

IV. Tested the unit.

V. Documented work.

Yes ________ No ________

____
Instructor's Signature
(Verifying Satisfactory Completion)

Date: ______________________

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

Scope of the Unit: After completion of this unit the student will be familiar with the correct test procedures to inspect components and component parts for reuse, and for documentation of the parts. The student should be able to discuss these procedures and score 85% on the evaluation.

LESSON 7: TEST COMPONENTS AFTER REASSEMBLY

Lesson Objectives - The student should be able to:

1. List two characteristics for which a component is tested.
2. Recall five items for which test methods should check.
3. List the steps of test procedures on pumps and valves.
4. State the standard to which test results should be compared.
5. Recognize correct storage procedures for overhauled parts.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: After a component has been overhauled it must be tested for correct operation before being put back in service or storage.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 7: TEST COMPONENTS AFTER REASSEMBLY

Outline: (Key Points)

I. Testing a component:

  A. A component is tested for both:

    1. Correct operating sequence

    2. Meeting performance specifications

    These tests must be performed at the same pressure and flow that the component will be subjected to in service.

  B. Equipment used in testing - The two major test beds that are used for testing overhauled components are:

    1. A test bench, either commercially built or constructed by overhaul shop

    2. Equipment component is used on but modified to accept test equipment as required.

  C. Test equipment - The two main test components are:

    1. Pressure gage

    2. Flow meter

    (Note - Both pieces are sized to handle maximum flow and pressure to be tested.)

II. Test methods - The methods used to test a component should check for such items as:

  A. Leak rate

  B. Volumetric efficiency

  C. Response time

  D. Correct operation

  E. Fluid leakage at component sealing surfaces

III. Testing methods

  A. Pumps - See Unit 2, Lessons 3 and 4 of this series.

B. Directional control valves, internal drain - See Unit 2, Lesson 6 of this series.

C. Pressure control valves - See Unit 2, Lesson 7 of this series.

IV. Test results - After a component is overhauled it should meet the performance specifications of a new component. Therefore, always compare test results of overhauled components to new equipment specifications.

V. Storage after testing - If a tested component is to be stored and not used immediately, the following operations should be performed.

A. Clean part.

B. Lubricate part.

C. Fill part with fluid, if required (ex: Fill case of pumps and motors).

D. Plug all ports to reduce risk of contamination.

E. Protect sealing surfaces from damage (ex. board bolted to exposed sealing surfaces).

F. Store component in adequate box.

G. Add desiccant package to box to prevent rusting.

H. Label storage box as to what it contains.

I. Seal box to prevent contamination.

J. Store box in clean, cool, dry place.

K. Document location of box in equipment file.

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 7: TEST COMPONENTS AFTER REASSEMBLY

Interaction Items: (Review Items)

1. Discuss safety precautions to be taken when testing equipment.
2. Discuss comparison of test results to original equipment specifications.
3. Discuss methods of storage for equipment with which students are familiar.
4. Show pictures of commercially produced test benches.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 7: TEST COMPONENTS AFTER REASSEMBLY

Evaluation Items:

1. State two characteristics for which a component is tested.

   a.

   b.

2. List five items for which test methods should check.

   a.

   b.

   c.

   d.

   e.

3. Discuss the testing procedure on a pump.

4. What standards should test results of overhauled equipment meet?

5. What procedure should be followed in storing an overhauled component?

   a.

   b.

   c.

   d.

   e.

   f.

   g.

   h.

   i.

   j.

LESSON 7: TEST COMPONENTS AFTER REASSEMBLY

Answers to Evaluation Items:

1. a. Correct operation sequence
   b. Meeting performance specifications

2. a. Leak rate
   b. Volumetric efficiency
   c. Response time
   d. Correct operation
   e. Fluid leakage at joints

3. Discussion should cover major points in Unit 2, Lessons 3 and 4 of this series.

4. Performance specifications for new equipment

5. a. Clean part.
   b. Lubricate part.
   c. Fill part with fluid, if required (ex: Fill case of pumps and motors).
   d. Plug all ports to reduce risk of contamination.
   e. Protect sealing surfaces from damage (ex. board bolted to exposed sealing surfaces).
   f. Store component in adequate box.
   g. Add desiccant package to box to prevent rusting.
   h. Label storage box as to what it contains.
   i. Seal box to prevent contamination.
   j. Store box in clean, cool, dry place.
   k. Document location of box in equipment file.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

Scope of the Unit: After completion of this unit the student will be familiar with the correct test procedures to inspect components and component parts for reuse, and for documentation of the parts. The student should be able to discuss these procedures and score 85% on the evaluation.

LESSON 8: DOCUMENTATION OF OVERHAUL

Lesson Objectives - the student should be able to:

1. Recall what should be done with service manuals.

2. List two types of schedules which should be updated after an overhaul.

3.1 Explain why the spare parts inventory must be checked after any overhaul.

3.2 Name three places where a list of spare parts used in an overhaul should be filed.

4. List the information about the overhaul which should be placed in the machinery file.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

Review Information Lesson 2-8 of this guide.

References: (Instructor's Additional Information)

Introduction: Before the overhaul of a hydraulic component can be considered complete, the necessary documentation must be prepared and filed. This recordkeeping is essential to insure that maintenance work is done on schedule and to the correct specifications.

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 8: DOCUMENTATION OF OVERHAUL

Outline: (Key Points)

I. Service manuals

   A. Replace in file after use so they are available next time.

   B. Add to manual any comments that will help in overhaul next time.

   C. Obtain replacement if manual is damaged during overhaul.

II. Lubrication schedule - When component was overhauled, the proper lubrication was done at that time. Document this data on the lubrication schedule so a new sequence can be started.

III. Preventive maintenance schedule - Do same as on lubrication schedule.

IV. Spare parts inventory - Check inventory of spare parts against what was used during overhaul and reorder as required.

V. Spare parts list - Record what parts were replaced and distribute a copy to:

   A. Machinery file - So documentation stays with equipment.

   B. Cost out file - So proper accounting can be processed.

   C. Inventory control person

VI. Machinery file - Place a note in the master machinery file that details:

   A. What work was performed

   B. Who performed the work

   C. Why work was done

   D. When was it done - date

   E. How long it took

   F. What parts were used

   G. Any special observations or notes

   H. Results from test of overhauled component

Fluid Power Systems Maintenance and Operation

Unit 3: Overhaul/Recondition Hydraulic Equipment

LESSON 8: DOCUMENTATION OF OVERHAUL

Interaction Items: (Review Items)

1. Discuss the importance of documentation of any overhaul.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 8: DOCUMENTATION OF OVERHAUL

Evaluation Items:

1. What should be done with service manuals after an overhaul is performed?

   a.

   b.

   c.

2. After an overhaul, what schedules should be updated?

   a.

   b.

3. Why should the spare parts inventory be checked after any overhaul?

4. Name three places where a list of spare parts used in an overhaul should be filed.

   a.

   b.

   c.

5. What information should be placed in the machinery file after an overhaul?

   a.

   b.

   c.

   d.

   e.

   f.

   g.

   h.

LESSON 8: DOCUMENTATION OF OVERHAUL

Answers to Evaluation Items:

1. a. Replace file.
   b. Add special notes.
   c. Obtain a new copy if damaged.

2. a. Lubrication
   b. Preventive maintenance

3. To reorder part(s) if necessary

4. a. Machinery file
   b. Cost out file
   c. Inventory file

5. a. What work was performed
   b. Who performed work
   c. Why work was done
   d. Date
   e. How long it took
   f. What parts were used
   g. Special notes
   h. Test results after overhaul

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

Scope of the Unit: After completion of this unit the student will be familiar with how, why, and when oil samples are taken and tested.

LESSON 1: WHY, WHEN, AND HOW TO TAKE A FLUID SAMPLE FOR TESTING

Lesson Objectives - the student should be able to:

1.1 List the properties analyzed by field tests of fluid samples.

1.2 List the properties analyzed by laboratory tests of fluid samples.

2. State three reasons for testing fluid samples.

3.1 Describe situations when a field test should be performed on a fluid.

3.2 State when laboratory tests should be performed on fluid samples from various types of equipment.

4.1 Describe conditions which must be met before taking a fluid sample.

4.2 Identify the point from which a fluid sample should be taken for a laboratory test.

5. List the steps in cleaning oil sample containers.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

Review Lesson 9: Hydraulic Fluids from Fluid Power/Basic Hydraulics

References: (Instructor's Additional Information)

Oil supplier information sheet

Instructional Materials Laboratory. Fluid Power/Basic Hydraulics. Columbia, Missouri: IML, 1983.

Introduction: Before the oil embargo of the early 1970's, oil was a relatively inexpensive material. Because of the low cost many people would just drain and replace their hydraulic fluid periodically. Today this practice of periodic fluid change has been replaced with the method where fluid is drained and replaced only when tests on the fluid show that the oil must be changed. This method has led to reduced oil cost, reduced maintenance costs, longer component life, and cleaner hydraulic systems.

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

LESSON 1: WHY, WHEN, AND HOW TO TAKE A FLUID SAMPLE FOR TESTING

Outline: (Key Points)

I. Type of testing - There are two basic series of tests.

  A. Field test - This series of tests is conducted on the fluid in the plant. These tests check:

    1. Color comparison
    2. Odor
    3. Settling out of particulates (contamination)
    4. Patch test

  B. Laboratory test - This series of tests is conducted by an oil laboratory. They will check the oil for:

    1. Change in viscosity
    2. Change in viscosity index
    3. Depletion of additives
    4. Contamination
      a. Amount and type of solids
      b. Chemical reaction

II. Why should testing be done?

  A. To determine if fluid has become contaminated while in use from:

    1. Airborne contamination (lint, dust, sand, metal particles, etc.)
    2. Chemical reactions due to heat or impurities.
    3. Component failure resulting in sludge, acids, etc.
    4. Normal wear of component, resulting in metal particles in the fluid.

  B. Oil testing can:

    1. Give an indication of system component condition by analysis of metal particles in fluid.

2. Determine if system filtration is adequate.

3. Determine when system must be drained and cleaned.

4. Suggest design changes to system based on oil life.

C. Reduce cost by:

1. Replacing fluid only when required.

2. Filtering or reconditioning fluid instead of replacing it.

III. When to test fluid - A fluid sample should be taken and analyzed by:

A. Field test

1. Every time a component has failed

2. Every time any component is added to or removed from a system

3. Every time a machine that has been out of service or in storage for any length of time is placed back in service

4. Every 2 - 3 months (based on experience with machine)

5. If equipment is moved

B. Laboratory test - Depending on use and type of equipment and components.

1. Once a year for normal type of equipment

2. Every six months for equipment that operates at high temperatures or in contaminated environments

3. Every three months for equipment that contains servo operated equipment such as industrial robots

IV. Sampling procedures

A. For water contamination

1. Before taking this sample, the machine must sit idle long enough for the reservoir and its contents to return to ambient temperature.

2. Test procedure for fluids whose specific gravity is less than water

a. Open reservoir fill port.

b. Using syringes with plastic tubing, draw a fluid sample off the bottom of reservoir.

c. Place fluid sample in clear glass test tube.

        - d. Let stand until separation takes place.
        - e. Do a visual inspection for water in lower portion of test tube.
    3. Water in solution with fluid must be determined using laboratory testing methods. Sample is taken using fluid sampling procedure below.

B. Fluid sampling procedures for field and laboratory testing.

1. Operate system until both of the following conditions are met:
    - a. System is at normal operating temperatures
    - b. Time calculated by the following equation

$$\text{time} = \frac{(\text{Reservoir size})(5)}{\text{Pump displacement}}$$

where time is in minutes, reservoir size is in gallons, and pump displacement is in gallons per minute.

2. Turn off system.
3. Open reservoir fill port.
4. Using a syringe with plastic tubing, draw a fluid sample from a location three inches off of the bottom of the reservoir.
5. Place sample in clean container until tested.
6. Mark sample as to where it came from and when it was taken.

V. Storage containers

A. Type - Glass is the best material for storing an oil sample because it:

1. Is easily cleaned
2. Is transparent
3. Will not react with fluid

B. Cleanliness - The container used to hold fluid sample must be absolutely clean and free of all types of contamination.

C. Cleaning procedure

1. Wash with soap and hot water.
2. Dry with lint free paper towel.

3. Flush with liquid freon a minimum of two times.
4. Set on lint free paper towel, open side down, until used.

Interaction Items: (Review Items)

1. Discuss how oil sampling results can be used in a preventive maintenance program.
2. How can oil sampling results predict component failure?
3. Discuss high pressure sampling techniques used in robotics.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 1: WHY, WHEN, AND HOW TO TAKE A FLUID SAMPLE FOR TESTING

Evaluation Items:

1.1 List the properties analyzed by a field test.

a.

b.

c.

d.

1.2 List the properties analyzed by a laboratory test.

a.

b.

c.

d.

2. Why should testing be done?

a.

b.

c.

3.1 When should a field test be performed on a fluid?

a.

b.

c.

d.

e.

3.2 When should a laboratory test be performed on a fluid from:

a. Normal equipment?

b. High temperature operation?

    c. Robot?

4.1 Before a sample is taken the system should be operated for how long?

    a.

    b.

4.2 From what point should a fluid sample be taken for a laboratory test?

    a.

    b.

5. List the procedure for cleaning oil sample containers.

    a.

    b.

    c.

    d.

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

LESSON 1: WHY, WHEN, AND HOW TO TAKE A FLUID SAMPLE FOR TESTING

Answers to Evaluation Items:

1.1 a. Color
  b. Smell
  c. Contamination
  d. Patch test

1.2 a. Change in viscosity
  b. Change in viscosity index
  c. Depletion of additives
  d. Contamination

2. a. To determine if contamination has occured
  b. Reduce cost
  c. Suggest changes or condition of system

3.1 a. Component failure
  b. Component change
  c. Machine placed back in service
  d. Every 2 - 3 months
  e. If equipment is moved

3.2 a. Once a year
  b. Every six months
  c. Every three months

4.1 a. Until it is at normal operating temperatures
  b. $\text{time} = \dfrac{(\text{Reservoir size})(5)}{\text{Pump Displacement}}$

4.2 Three inches from the bottom of the reservoir

5. a. Wash with soap and hot water.
  b. Dry.
  c. Flush two times with liquid freon.
  d. Set upside down on paper towel until used.

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

Scope of the Unit: After completion of this unit the student will be familiar with how, why, and when oil samples are taken and tested.

LESSON 2: OIL PERFORMANCE SPECIFICATIONS

Lesson Objectives - the student should be able to:

1. Recall what fluid specifications are required by hydraulic equipment manufacturers.
2. Define Beta 10 rating and discuss how it is used.
3. Recall precautions to take when changing types of fluid.
4. Define viscosity.
5. Define viscosity index.
6. Define specific gravity and explain why it is important.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

Review Lesson 2 - 9 from Fluid Power/Basic Hydraulics

References: (Instructor's Additional Information)

Fluid Power/Basic Hydraulics. Columbia, Missouri: Instructional Materials Laboratory, 1983.

Introduction: To prevent premature component failure, it is important to use the type of oil suggested by the equipment manufacturer.

LESSON 2: OIL PERFORMANCE SPECIFICATIONS

Outline: (Key Points)

I. Fluid specifications - Most hydraulic equipment manufacturers issue a fluid recommendation list for use in their equipment. This list states what specifications the fluid used in the system should meet. Some of these recommendations may be:

   A. Cleanliness standard

   B. Compatibility with seals

   C. Viscosity

   D. Viscosity index

   E. Additive package

   F. Specific gravity, if fire resistant fluids are used

   (Note - An oil laboratory can analyze oil samples to determine the items listed in sections II - VII. On large volume systems it is cost efficient to have a complete laboratory test run to determine if the system fluid requires change.)

II. Cleanliness - The manufacturer lists what the cleanliness of the system should be, based on one of the following ratings:

   A. Filtration - the micron rating of filter which should be used in the system.

   B. Beta 10 rating - the ratio of particles greater than 10 micrometers entering the filter divided by the number of particles greater than 10 micrometers leaving the filter.

   C. ISO code - International Standards Organization cleanliness rating.

III. Compatibility:

   A. Fluid used in a system must be compatible with seal material used in components. Check fluid seal material compatibility chart.

   B. Consult fluid supplier for special instructions, precautions to be taken when changing from oil to fire resistant fluid or from fire resistant fluid to oil. It is advisable to check even when changing types of petroleum-based fluids.

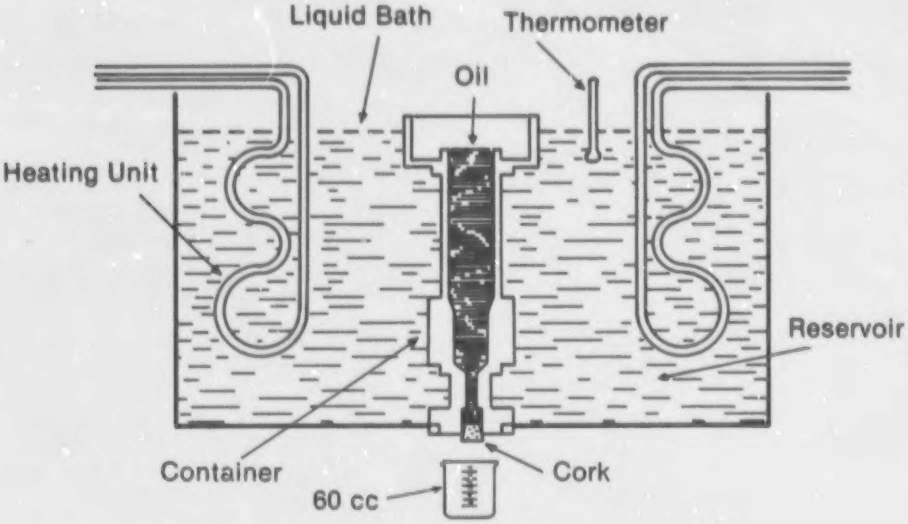
IV. Viscosity:

A. Viscosity is the resistance of a liquid to flow.

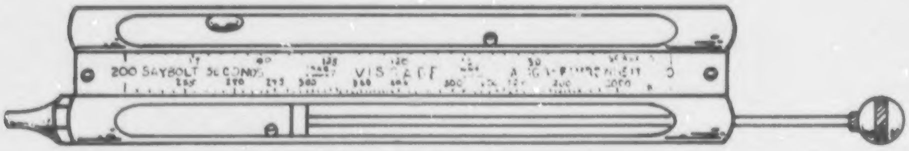
B. Viscosity changes with temperature.

C. Common viscosity unit of measurement is the Saybolt Universal Second - usually abbreviated SSU or SUS.

D. The procedure for measuring Saybolt viscosity is: A quantity of oil is heated to one of three (3) temperatures, 100°F, 130°F, or 210°F (depending upon viscosity). The time required for 60 cubic centimeters of oil to run through a specified size hole is measured in seconds. The number of seconds is the Saybolt viscosity.


Liquid Bath
Thermometer
Oil
Heating Unit
Reservoir
Container
Cork
60 cc

E. Comparison check - For a quick field test of oil viscosity, a comparison device can be used. The device consists of one tube containing a known viscosity fluid and a second tube filled with the fluid to be tested. By comparing the movement of a small ball within each of the two tubes, a relatively accurate viscosity reading can be obtained.


200 SAYBOLT SECONDS
VIS

V. Viscosity index - a term which expresses the change in viscosity as the temperature changes.

   A. The higher the viscosity index the smaller the change in viscosity with a given change in temperature.

   B. Viscosity index is a purely relative term; it has no units. It is just a number used to express the relative viscosity between two arbitrary limits.

   C. The change in viscosity of Pennsylvania crudes between 100 and 210°F is rated at 100. This value is sometimes used as a standard of comparison.

VI. Specific gravity:

   A. Specific gravity is the ratio of the weight of any volume of a substance compared to the weight of an equal volume of pure water.

   B. Most fire resistant fluids have a higher specific gravity than petroleum based fluids. This "heavier" fluid lowers the suction characteristics of a pump's inlet, increasing the tendency of cavitation and early pump failure.

VII. Additive package - All good hydraulic oils will provide the following:

   A. Oxidation inhibitor

   B. Rust and corrosion protection

   C. Antiwear properties

   D. Good water separating ability

   E. Anti-foam agents

LESSON 2: OIL PERFORMANCE SPECIFICATIONS

Interaction Items: (Review Items)

1. Show an equipment manufacturer's oil recommendation list to the students.
2. Discuss why the type of oil used in the lab was chosen.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 2: OIL PERFORMANCE SPECIFICATIONS

Evaluation Items:

1. What specifications do hydraulic equipment manufacturers recommend for the system fluid used in their equipment?

   a.

   b.

   c.

   d.

   e.

   f.

2. Define Beta 10 rating and tell how it is used.

3. What precautions should be taken when changing from one type of fluid to another?

   a.

   b.

4.1 Define viscosity.

4.2 Viscosity is usually measured in what units?

5. What is viscosity index?

6.1 Define specific gravity.

6.2 State the problem often encountered with fluids which have high specific gravity.

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

LESSON 2: OIL PERFORMANCE SPECIFICATIONS

Answers to Evaluation Items:

1. a. Cleanliness standard
   b. Compatibility with seals
   c. Viscosity
   d. Viscosity index
   e. Additive package
   f. Specific gravity

2. This is the ratio of the number of particles greater than 10 micrometers entering the filter divided by the number of particles greater than 10 micrometers leaving the filter. It is used as a measure of fluid cleanliness.

3. a. Check seal compatibility.
   b. Consult with oil supplier for flushing (cleaning) instruction.

4.1 A liquid's resistance to flow

4.2 Saybolt Universal Seconds

5. A term which expresses the change in viscosity as the temperature changes

6.1 Specific gravity is the ratio of the weight of any volume of a substance compared to the weight of an equal volume of pure water.

6.2 Pump cavitation

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

Scope of the Unit: After completion of this unit the student will be familiar with how, why, and when oil samples are taken and tested.

LESSON 3: PERFORMING A PATCH TEST (DEMONSTRATION LESSON)

Lesson Objectives - the student should be able to:

1. Take a fluid sample properly.
2. Perform a patch test.
3. Perform a visual oil inspection.
4. Make recommendations for oil treatment based on test.

Supplementary Teaching/Learning Items:

1. Instruction sheet for patch test kit. (Bulletin 90004B), available from The Oilgear Comany, Milwaukee, WI 53219

Informational Assignment: (Student)

Review Unit 4, Lesson 1

References: (Instructor's Additional Information)

Literature from patch test kit manufacturer

Introduction: Clean oil is an absolute necessity for long system life. Periodic checks of system fluid by a patch test and visual inspection must be made.

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

LESSON 3: PERFORMING A PATCH TEST

Tools, Equipment, and Materials:

Patch test kit
Lint free paper towels
Safety glass

Steps of Procedure: (Job Sheet)

I. Clean one test tube and one beaker per Unit 4, Lesson 1, section VII.

II. Take two (2) fluid samples.

   A. Place one sample in test tube and let stand.

   B. Place one sample in beaker.

III. Perform patch test.

   A. Fill syringe to required level - usually 20 ccs.

   B. Insert clean filter paper in syringe housing. Note - Use forceps to handle filter paper to avoid contamination from fingers.

   C. Point syringe into large waste oil beaker.

   D. Push down on syringe plunger to force oil sample through filter paper.

   E. Refill syringe and repeat steps C and D until 40 ccs of oil have passed through filter paper.

   F. Fill syringe with 5 ccs of liquid freon.

   G. Repeat step C.

   H. Push down on syringe plunger to force freon through filter paper to wash away oil (leaving contamination behind on paper).

   I. Pump syringe 10 - 20 times to draw air through filter paper to dry it.

   J. Repeat steps F through I.

   K. Remove filter paper, with forceps, and place between two glass slides.

   L. Inspect filter paper, using 10 power magnifier.

(Note - Any particle with a clearly defined shape is over 25 micron (.001 inch) in size.)

M. Record observations:

1. Number of large particles ____________________________

2. Type of particles (ex. metal, fiber, grit, etc.)

____

____

____

N. Compare color of filter paper to comparison chart (supplied with patch test kit) and record information.

O. Compare color intensity of filter paper to comparison chart and record information.

P. Compare test information to evaluation acceptability chart (supplied with patch test kit).

Q. Reach a conclusion as to what (if anything) should be done to system fluid based on patch test (check one)

_____ 1. Acceptable

_____ 2. Auxiliary filtration required

_____ 3. Drain, clean system, and replace with clean oil

IV. Visual inspection of test tube oil sample

A. Has water separated in test tube?

_____ yes _____ no

B. Compare oil sample to an unused oil sample of the same oil for:

1. Color or clarity

2. Odor

3. Feel

(Note - If there is a detectable difference in any of the above, perform auxiliary filtration.)

C. Reach a conclusion as to what (if anything) should be done to system fluid based on this visual inspection of oil sample (check one).

_____ 1. Acceptable

_____ 2. Auxiliary filtration required

_____ 3. Drain, clean system, and replace with clean oil

V. Reach a conclusion - Based on information from patch test and visual inspection test, what action should be taken?

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

LESSON 3: PERFORMING A PATCH TEST

Interaction Items: (Review Items)

1. Discuss why system fluid must be kept clean.
2. Show parts that have been removed from a contaminated system.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 4: Fluid Sampling

LESSON 3: PERFORMING A PATCH TEST

Evaluation Items:

The student has satisfactorily completed the following steps of procedure:

I. Correctly cleaned test equipment.

II. Taken a fluid sample.

III. Performed a patch test.

IV. Performed a visual inspection on system fluid.

V. Reached the correct conclusion about system fluid tested.

Yes ______ No ______

____
Instructor's Signature
(Verifying Satisfactory Completion)

Date: ______________________

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

Scope of Unit: After completion of this unit the student will be familiar with how to check calibration and make minor adjustments to test equipment, including pressure gages, deadweight testers, and flow meters.

LESSON 1: PRESSURE GAGES

Lesson Objectives - the student should be able to:

1. List when gages should be calibrated.
2.1 List types of equipment used in calibration of pressure gages.
2.2 Identify the standards to which calibration equipment should be traceable.
3. List three reasons for checking calibration.
4. Describe the procedure for checking calibration of pressure gages.
5. Define rezeroing.
6. Describe the procedure to correct a gage for sluggish operation.
7. Describe the function of a hairspring.
8. Recall how to adjust span reading.
9. Recall how to adjust rotary-movement gages for linearity.
10. Describe proper storage conditions for pressure gages.
11. Recognize the degrees of accuracy for the various types of pressure gages.

Supplementary Teaching/Learning Items:

1. TM-1 Component Parts of Bourdon Tube Gage

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Gage Manufacturer's Engineering Data Sheet

Introduction: A pressure gage is a precision testing tool and should be treated as such.

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 1: PRESSURE GAGES

Outline: (Key Points)

I. Calibration of pressure gages:

   A. Should be performed a minimum of once every six months.

   B. Should be performed at any time that the gage reading is suspected to be incorrect.

   C. Any time gage has been dropped or damaged.

   D. Calibration due date - A gage should have a calibration tag attached to it listing when gage is due for calibration. Date is six months since last calibration date. This tag should also contain the name of the person who performed the calibration.

II. Calibration equipment for positive pressure gage - calibration of gages should be performed using:

   A. Deadweight tester which has a current certification test record traceable to National Bureau of Standards

   B. Comparison test using a small hand pump and master test gage that has a current calibration certificate traceable to National Bureau of Standards

III. Why should calibration be performed on pressure gages?

   A. Gage reading must be known to be accurate.

   B. It is required by law in some industries.

   C. Gages can become damaged in service, especially under conditions of vibration or pressure pulsations. Although this damage may not be apparent, movement and linkage may become worn and moving parts contaminated with dirt. Very frequently, pointers move off of zero adjustment due to shock loading; therefore, gages in service should be calibrated every six months.

IV. Check calibration of pressure gages

   Pressure gage calibration is performed by pressurizing gage to each marked division and recording both master gage or deadweight test reading and reading of gage that is being checked. If readings are not the same, or:

   A. Pointer is not on correct marking of gage - it may need to be rezeroed.

B. If gage is out of accuracy range of manufacturer's tolerance specifications between 1/4 and 3/4 of full scale reading - gage needs to be serviced.

C. If gage sticks or hesitates - it needs to be serviced for sluggishness and binding.

D. Gage does not repeat - gage needs to be serviced. Check hairspring.

E. Pointer movement is uniform at uniform pressure changes but the pointer goes excessively beyond or is short of the maximum scale value when the maximum pressure is applied to gage, then span adjustment is required.

F. Linearity adjustment is required when the motion of the pointer either slows down or speeds up at the end of the range as the test pressure is increased in uniform increments.

V. Gage pointer adjustment - Calibration that can be corrected by repositioning pointer relative to the scale is called rezeroing the gage. This operation is done at midscale.

A. Some gages are made with easily adjustable pointer reset devices that do not require removal of the pointer from the movement. Pointer reset devices are:

1. Micrometer adjustable gear type

2. Friction type

3. Rotating movements

B. When non-adjustable pointers are used:

1. Remove pointer with pointer jack.

2. Reposition and install at required position.

VI. Corrections and adjustments for treatment of sluggish action of gage

A. Clean all gears.

B. Clean all bearings.

C. Adjust hairspring - see section VII.

D. Check connecting link for binding - bend link slightly if required.

E. Check for excessive wear on parts.

F. Clear snubber orifice.

VII. Adjustment of hairspring

  A. The function of the hairspring is to take up clearance in the gear train and linkage assembly. Hairsprings must be adjusted very accurately to insure correct gage operation.

  B. Adjustment requirements:

    1. Hairsprings should be adjusted, with tweezers, to set spring perfectly in plane so that when wound up approximately 360° the spring will not distort.

    2. Wind hairsprings tightly enough to apply torque through the entire gage movement range.

VIII. Span adjustment - To adjust span reading:

  A. Reduce span range - increase pivot radius to reduce pointer travel.

  B. Increase span range - decrease pivot radius to increase pointer travel.

IX. Linearity adjustment

  A. For gages with rotary movement:

    1. To speed up the movement of the pointer at the end range - movement is rotated in the downward direction.

    2. To slow down the movement of the pointer at the end range - movement is rotated upward.

  B. For gages without rotary movement:

    1. Bend tip end of bourdon types.

    2. Substitution of a different length connection link.

  (Note - Readjustment of segment pivot radius is often required in conjunction with linearity adjustments.)

X. Gage storage - To protect components and maintain accuracy, all gages should be stored:

  A. In a place that is dust free

  B. With end caps to protect threads.

XI. Gage accuracy - Gages can be obtained with the following degrees of accuracy:

  A. General service - 2% of full scale reading

  B. Industrial service - 1% of full scale reading

C. Process service - 1/2 of 1% of full scale reading

D. Test gages - 1/4 of 1% of full scale reading

E. Specialist gages - 1/10 of 1% of full scale reading

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 1: PRESSURE GAGES

Interaction Items: (Review Items)

1. Discuss why calibration stickers on gages are necessary.
2. Discuss how test equipment is traceable to National Bureau of Standards.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 1: PRESSURE GAGES

Evaluation Items:

1. When should gages be calibrated?

   a.

   b.

   c.

2.1 What type of equipment is used to calibrate positive pressure gages?

   a.

   b.

2.2 Calibration equipment should be traceable for accuracy to what standards?

3. Why should gages be calibrated?

   a.

   b.

   c.

4. Gages should be checked in each ________ division when being calibrated.

5. What is rezeroing?

6. To correct a gage for sluggishness, check and do the following:

   a.

   b.

   c.

   d.

   e.

7. What does a hairspring do?

8. To adjust span reading:

   a. To increase span range, __________ pivot radius.

   b. To decrease span range, __________ pivot radius.

9. To adjust linearity in a gage with rotary movement:

   a. To speed up pointer movement at the end range, rotate movement in the __________ direction.

   b. To slow down pointer movement at the end range, rotate movement in the __________ direction.

10. How should pressure gages be stored?

    a.

    b.

11. Put a (+) beside the gage with the highest degree of accuracy. Put a (-) beside the gage with the lowest degree of accuracy.

    _____ a. General service gage

    _____ b. Test gage

    _____ c. Process service gage

    _____ d. Specialist gage

    _____ e. Industrial service gage

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 1: PRESSURE GAGES

Answers to Evaluation Items:

1. a. Every six months
   b. Anytime reading is suspicious
   c. Anytime gage is damaged

2.1 a. Deadweight tester
    b. Master test gage

2.2 National Bureau of Standards

3. a. Reading must be known to be accurate
   b. May be required by law
   c. Gages can become damaged without knowing it

4. Marked

5. Calibration that can be corrected by repositioning pointer relative to scale.

6. a. Clean all gears
   b. Clean all bearings
   c. Adjust hairsprings
   d. Check for binding of connecting links
   e. Check for wear

7. Take up clearance in the gear train

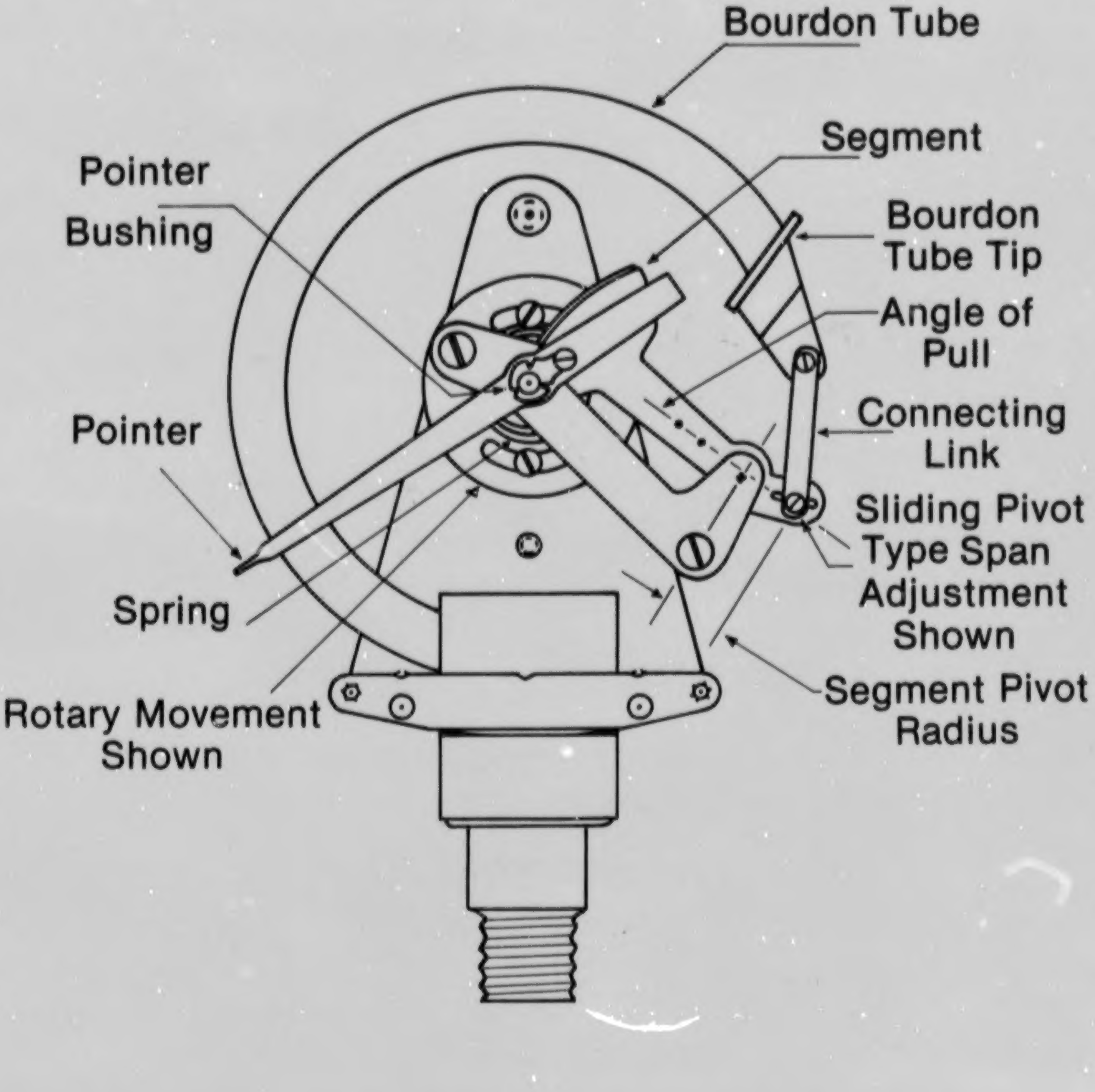
8. a. Decrease
   b. Increase

9. a. Downward
   b. Upward

10. a. In a place that is dust-free
    b. With end caps to protect threads

11. a. -
    b.
    c.
    d. +
    e.

Component Parts of a Bourdon Tube Gage


Bourdon Tube
Segment
Pointer
Bushing
Bourdon Tube Tip
Angle of Pull
Pointer
Connecting Link
Sliding Pivot Type Span Adjustment Shown
Spring
Rotary Movement Shown
Segment Pivot Radius

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

Scope of Unit: After completion of this unit the student will be familiar with how to check calibration and make minor adjustments to test equipment, including pressure gages, deadweight testers, and flow meters.

LESSON 2: DEADWEIGHT TESTER

Lesson Objectives - the student should be able to:

1. Explain the principle of operation of a deadweight tester.
2. Recall what affects the accuracy of tests using a deadweight tester.
3. List the information which is stamped on weights used for test.
4. Describe proper care of test weights.
5. List the steps in the leveling procedure for a deadweight test.
6. List test procedure for a deadweight test.
7. Recall warning information about the use of oil filled test units.
8. Recall factors affecting calibration for extreme accuracy.

Supplementary Teaching/Learning Items:

1. TM-1 Portable Deadweight Tester

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Deadweight Tester Manual

Introduction: The deadweight tester is the most accurate equipment available to the small shop for calibration of pressure gages.

LESSON 2: DEADWEIGHT TESTER

Outline: (Key Points)

I. Principle of Operation - A deadweight gage tester is a hydraulic balance machine. Gravity acting on calibrated weights provides a force. This force is exerted on a known area, the piston chamber, creating a pressure which acts on the gage.

II. Accuracy - Deadweight testers are accurate to within 1/10 of 1% of the pressure being measured, provided that:

A. Weights have not been damaged.

B. Piston cylinders are not worn to the extent that leakage occurs.

C. Correct test and installation procedures are followed.

III. Pressure range - Some deadweight testers have two (2) piston/cylinder assemblies.

A. Low pressure assembly - 5 to 2,000 psig, but 10 psig minimum is recommended.

B. High pressure assembly - 25 to 10,000 psig, but 50 psig minimum is recommended.

IV. Weights

A. Weights are added to the plate and piston assembly to a value equivalent to the desired psig value to be tested. By adding weights to the plate, any pressure up to the maximum allowable pressure rating of the tester can be obtained.

B. Weight values stamped on weights are equivalent pressure values. Weights are stamped with both low pressure and high pressure equivalent value in terms of psig.

C. Deadweight tester weights are calibrated to very close tolerances. They are precision made and should not be filed on, chipped, scraped, or abused in any way since this will change their value.

D. Weights should be wiped clean before and after use.

E. Weights should be stored in their protective case when not in use.

V. Setting deadweight test level - The deadweight tester must be level to function accurately. To level unit:

A. Place bubble level on top of piston plate.

B. Revolve slowly

C. Shim as required between drip pan and work bench until bubble does not move as piston plate is rotated 360°.

(Note - Deadweight tester should be mounted securely to prevent movement out of level during operation.)

VI. Performing deadweight test

A. Connect gage or other pressure device to be tested to pipe assembly.

B. Add weight to piston plate to give desired calibration pressure.

C. Close fluid release valve.

D. Actuate pump until weights are lifted and floating freely.

(Note - This is done as weights are spun at slow speed.)

E. Spin weights by hand and record reading(s).

(Note - Weights must be kept spinning during the time readings are taken. Speed of rotation is unimportant, but rotation must not stop.)

F. Release fluid under pressure by opening fluid release valve after readings are taken.

VII. General precautions

A. Deadweight tester should be set up so the center line of the piston/cylinder assembly is vertical. Check level.

B. Weights must be carefully centered on the piston/cylinder assembly.

C. Piston must be kept rotating during test.

VIII. Warning

A. Tester should be filled with clean fluid.

B. Oil test units are not to be filled with water.

C. Only water test units are to be used in oxygen service. Do not use oil filled units on oxygen service equipment.

D. Relieve pressure before removing weights.

IX. Extreme accuracy calibrations - For extreme accuracy calibrations, the following must be considered:

A. Vibration of test unit

B. Change in gravity due to change in altitude

C. Temperature change on piston/cylinder assembly

D. Density of the atmosphere

E. Fluid head - height of gage being tested above piston/cylinder assembly

F. True levelness of test unit

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 2: DEADWEIGHT TESTER

Interaction Items: (Review Items)

1. Relate Pascal's law to the principle of operation of a deadweight tester.
2. Show relationship of accuracy (using trigonometry) for tester out of level.

Classrooom, Laboratory, Shop, or Other Activities:

Show equipment to class.

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 2: DEADWEIGHT TESTER

Evaluation Items:

1. Explain the principle of operation of a deadweight tester.

2. Deadweight tests are very accurate providing that:

   a.

   b.

   c.

3. Weights are stamped with what information?

4. How should weights be cared for?

   a.

   b.

   c.

5. How should the deadweight tester be leveled?

   a.

   b.

   c.

6. List procedure for deadweight test.

   a.

   b.

   c.

   d.

   e.

   f.

7. Oil filled test units are not to be used on what type of equipment?

8. What factors must be considered when calibrating for extreme accuracy?

   a.

   b.

   c.

   d.

   e.

   f.

LESSON 2: DEADWEIGHT TESTER

Answers to Evaluation Items:

1. Gravity acting on weight provides a force to create pressure to act on the gage

2. a. Weights are not damaged.
   b. Unit is not excessively worn.
   c. Correct test and installation procedures are followed.

3. Their pressure equivalents for both high and low pressure piston assemblies

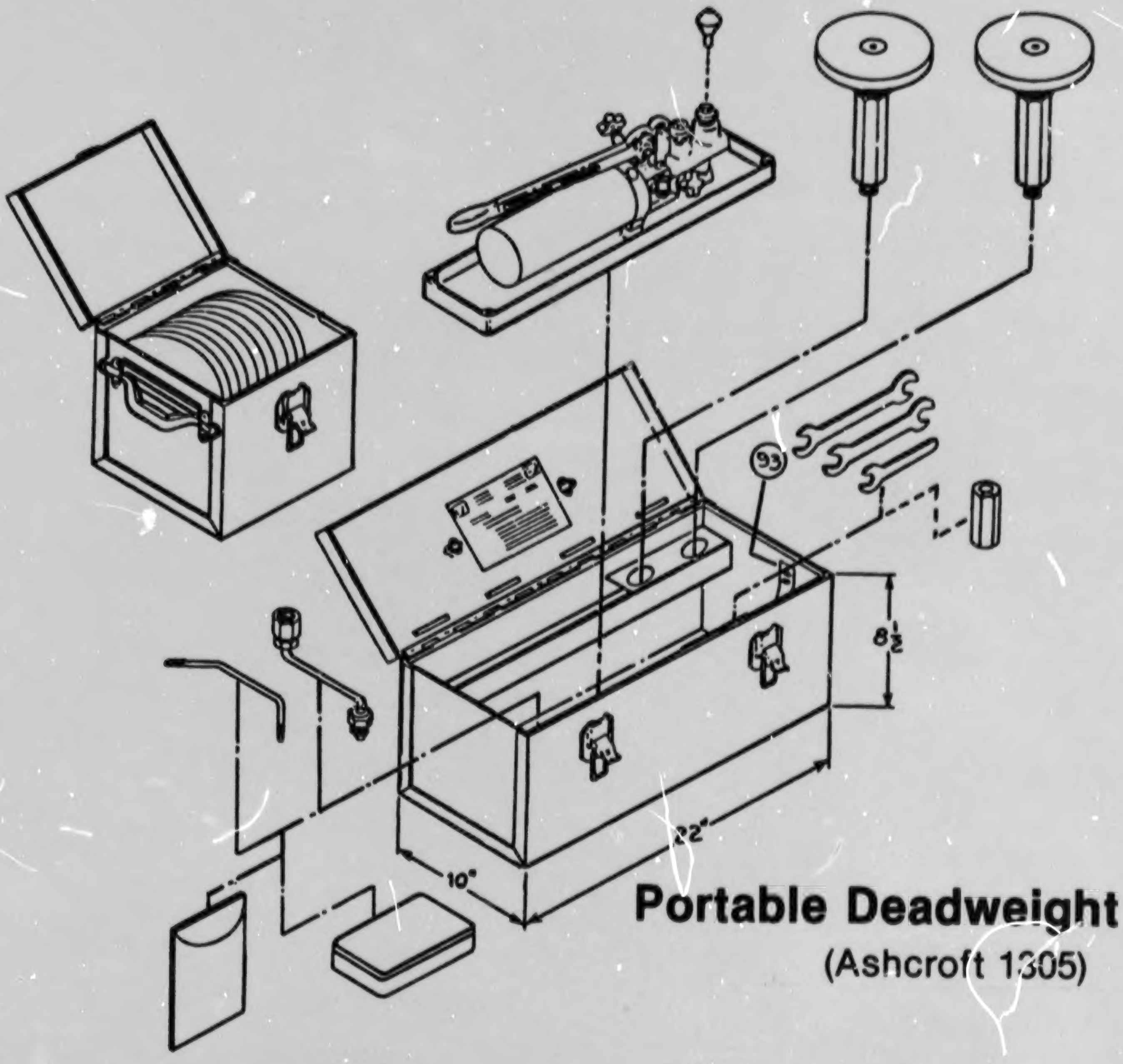
4. a. Never abused or filed on
   b. Cleaned before and after use
   c. Stored in protective box

5. a. Place bubble level on top of piston.
   b. Rotate slowly.
   c. Shim as required so there is no bubble movement in 360° rotation.

6. a. Connect gage.
   b. Add correct weights.
   c. Close valve.
   d. Pump while spinning until weights float.
   e. Spin weights and record reading.
   f. Open valve.

7. Oxygen service

8. a. Vibration
   b. Gravity due to elevation change
   c. Temperature
   d. Density of air
   e. Fluid head
   f. Levelness of test unit



Portable Deadweight Tester

(Ashcroft 1305)

TM-1

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

Scope of Unit: After completion of this unit the student will be familiar with how to check calibration and make minor adjustments to test equipment, including pressure gages, deadweight testers, and flow meters.

LESSON 3: PRESSURE GAGE CALIBRATION (DEMONSTRATION LESSON)

Lesson Objectives - the student should be able to:

1. Perform a visual inspection on a pressure gage.
2. Check calibration of gage using deadweight tester.
3. Perform or suggest repair work required.
4. Record test results.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

Review Unit V, Lessons 1 and 2.

References: (Instructor's Additional Information)

Introduction: The lesson is to demonstrate the use of a deadweight tester and how pressure gages are calibrated.

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 3: PRESSURE GAGE CALIBRATION

Tools, Equipment, and Materials:

Deadweight tester
Pressure gage
Safety glasses
Small hand tools as required

Steps of Procedure: (Job Sheet)

	X	Comments
I. Clean gage		
A. Wipe off gage.		
B. Remove any thread dope from threads.		
II. Visual inspection		
A. Glass is OK.		
B. Dial face is OK.		
C. Pointer is not bent.		
D. Threads are not damaged.		
E. Case is intact.		
III. Test gage at midscale		
A. Connect gage to tester.		
B. Place weights on tester to check at midscale.		
C. Close fluid release valve.		
D. Actuate pump until weights are lifted and floating free.		
E. Spin weights slowly and check gage reading. Is gage recording correct value?		

	X	Comments
F. If not, "rezero" gage by use of pointer reset device and reinstalling.		
G. Recheck if step F was done.		
H. Remove all weights from tester.		
IV. Test gage for sticking, repeating, and linearity A. Check gage at zero.		
B. Add weights and check at each major division. Record readings. 1. Tap gage before taking readings at lower pressure readings.		
2. Observe any tendency for sticking of pointer.		
3. Check linearity.		
C. After maximum pressure is tested, remove weights and release fluid (as required) to check each major division on the way back to zero. 1. Observe any tendency for sticking of pointer.		
V. Check results and suggest or make (instructor's option) any adjustments or repairs as required.		
VI. Repeat steps III and IV if any repairs are performed.		
VII. Records A. Attach current calibration sticker to gage.		
B. Record test results in record book.		

LESSON 3: PRESSURE GAGE CALIBRATION

Interaction Items: (Review Items)

1. Review procedure.
2. Stress safety rules during testing.

Classroom, Laboratory, Shop, or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 3: PRESSURE GAGE CALIBRATION

Evaluation Items:

The student has satisfactorily completed the following steps of procedure:

I. Checked calibration of a pressure gage.

II. Demonstrated correct use of a deadweight tester.

III. Repaired or suggested repairs of a pressure gage.

IV. Recorded test results.

Yes ______ No ______

____
Instructor's Signature
(Verifying Satisfactory Completion)

Date: ______________________

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

Scope of Unit: After completion of this unit, the student will be familiar with how to check calibration and make minor adjustments to test equipment, including pressure gages, deadweight testers, and flow meters.

LESSON 4: FLOW METERS

Lesson Objectives - the student should be able to:

1. State when flow meters should be calibrated.
2. Recall why flow meters should be calibrated.
3. List variables that affect gage readings.
4. State what a certified calibration is.
5. List three (3) methods of checking calibration.

Supplementary Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: Flow gages are very useful troubleshooting tools if the gage readings are known to be correct.

LESSON 4: FLOW METERS

Outline: (Key Points)

- I. Required calibration of flow gages
  - A. Calibration should be performed:
    - 1. A minimum of once every six months
    - 2. Any time that the gage reading is suspected to be incorrect
    - 3. If gage has been dropped or damaged
  - B. Calibration due date - All flow gages should have a tag attached listing:
    - 1. When gage is due for calibration (six months from last calibration date)
    - 2. Name of person who performed the calibration.
- II. Reasons for calibration of flow gages
  - A. Gage readings must be known to be accurate.
  - B. Calibration is required by law in some industries.
  - C. Gages can become damaged in service.
- III. Variables affecting gage readings
  - A. Type of fluid
  - B. Operating temperature of gage and fluid
  - C. Direction of flow
  - D. Viscosity of fluid
  - E. Operating pressure at flow gage
  - F. Flow rate or range
- IV. Certified calibration
  - A. A certified calibration means that the gage has been checked by someone who can issue a certificate stating that the gage reading is:

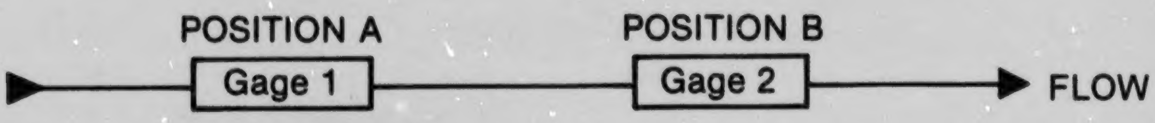
    1. Correct
    2. Traceable to National Bureau of Standards

- B. Calibration equipment - Calibration of flow gages is performed on a test flow bench that can duplicate the actual working conditions of the gage for:
    1. Type of fluid
    2. Temperature
    3. Direction of flow
    4. Fluid viscosity
    5. Operating pressure
    6. Flow range

V. Checking calibration in plant

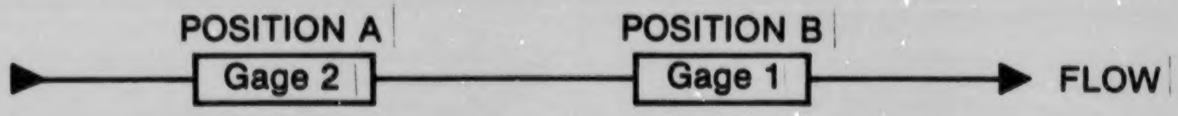
Note - Since most companies do not have a flow test bench for checking calibration of flow gages, certified calibration cannot be performed in most plants.

- A. Comparison check - Relative flow gage accuracy can be compared to other gages, using one of the following methods, to determine if gage is approximately correct. This is not a certified calibration.
    1. Method #1 - Comparison against a known correct gage
        - a. Set up a flow path and install a gage that is known to be correct.
        - b. Record reading from known gage.
        - c. Remove known gage and install second gage.
        - d. Record second gage reading and compare to reading from known gage. If they are aproximately the same, assume the gage is accurate.
    2. Method #2 - Comparison of two gages
        - a. Install gages as shown.



        - b. Record readings.

c. Reconnect gages as shown.



d. Record readings

e. Compare gage readings. If gages are accurate, the following statements will be true:

Gage #1 reading when installed in position A will be approximately equal to gage #2 reading when installed in position A.

AND

Gage #1 reading when installed in position B will be approximately equal to gage #2 reading when installed in position B.

B. Actual flow measurement comparison

1. Connect flow gage in circuit

2. Connect discharge line to a known volume container.

3. Run system and:

   a. Record flow meter reading

   b. Record (in seconds) the time required to fill container

4. Calculate flow

$$\text{Flow} = \frac{\text{Volume Size}}{(t)(60)}$$

where:

Flow is in gallons per minute
Volume size is in gallons
Time is in seconds

5. Compare flow meter recorded value to calculated value.

LESSON 4: FLOW METERS

Interaction Items: (Review Items)

1. Review how the calibration of flow meters in your shop could be checked.
2. Discuss how temperature affects flow meter reading.

Classroom, Laboratory, Shop, or Other Activities:

Demonstrate checking of flow meter in shop using method from section V.B.

LESSON 4: FLOW METERS

---

1. When should flow meters be calibrated?

   a.

   b.

   c.

2. Why should flow meters be calibrated?

   a.

   b.

   c.

3. What are the variables that affect gage readings?

   a.

   b.

   c.

   d.

   e.

   f.

4. What is a certified calibration?

5. List three methods of checking calibration.

   a.

   b.

   c.

Fluid Power Systems Maintenance and Operation

Unit 5: Test Equipment

LESSON 4: FLOW METERS

Answers to Evaluation Items:

1. a. Every six months
   b. Anytime reading is suspect
   c. Anytime damaged or dropped

2. a. Readings must be known to be accurate
   b. May be required by law
   c. Can be damaged in service

3. a. Type of fluid
   b. Operating temperature
   c. Direction of flow
   d. Viscosity of fluid
   e. Pressure
   f. Flow rate

4. A certified calibration states that the:

   a. Gage is correct
   b. Traceable to National Bureau of Standards

5. a. Comparison against a known standard
   b. Comparison of readings from gages
   c. Flow measurement comparison

Fluid Power Systems Maintenance and Operation

Unit 6: Service Equipment

Scope of the Unit: This unit introduces the student to the use of a hydraulic filter buggy, including recognition of when to change filters and precautionary measures to avoid contamination of system fluid.

LESSON 1: HYDRAULIC FILTER BUGGY

Lesson Objectives - the student should be able to:

1. List the equipment contained on a hydraulic filter buggy.
2. Discuss four uses of a filter buggy.

3.1 Identify the correct micron rating for filters on a hydraulic filter buggy.

3.2 List times when filters on a hydraulic filter buggy should be changed.

3.3 State the precaution which must be observed when changing filters.

4. List the steps to prevent contamination which must be taken before using the hydraulic filter buggy.

Suggested Teaching/Learning Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Introduction: Maintenance and component failure on a hydraulic system can be greatly reduced if the oil is kept clean. The hydraulic filter buggy unit assists by filtering out and removing contaminants.

Fluid Power Systems Maintenance and Operation

Unit 6: Service Equipment

LESSON 1: HYDRAULIC FILTER BUGGY

Outline: (Key Points)

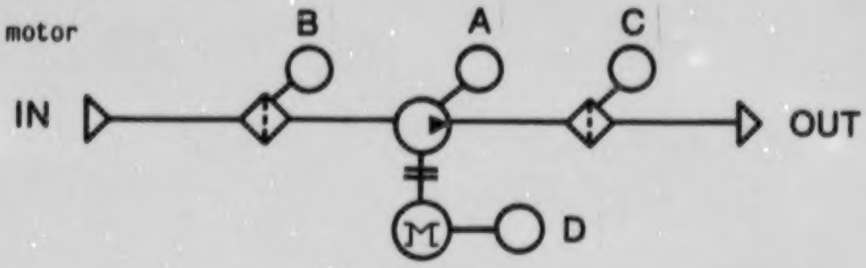
I. Description - A portable filter buggy is a cart that contains the following equipment:

   A. Pump - normal size, 4-20 GPM

   B. Pre-strainer

   C. 3 micron filter

   D. Electric motor



II. Use - A portable filter buggy can be used to:

   A. Fill hydraulic units - Since oil received in drums is contaminated (or assumed to be so) no fluid should be added to a hydraulic system without being filtered first through this cart.

   B. Component failure - Any time a component fails on a hydraulic system there is a chance that contamination is released into the system. During replacement of the failed component the filter buggy should be attached to the reservoir to remove any contamination present.

   C. Auxiliary filtration - If laboratory or patch tests indicate a need for additional filtration, this unit can be used.

   D. Transfer pump - If required, this unit can be used to remove oil from a hydraulic reservoir during repair or clean-up operations.

III. Filter changes

   A. 3 micron filter(s) are to be used when changing filters.

   B. Filter(s) should be changed any time a different type (not grade) of fluid is pumped through the unit.

   C. Filter(s) should be changed when dirt indicator says so.

   D. Care should be taken not to introduce dirt into unit when changing filter(s).

IV. Cleaning - Before using:

A. Clean fitting(s) and hose that is going to enter reservoir or oil drum.

B. Inspect unit to make sure cross contamination of oil will not take place.

C. Inspect dirt indicator as soon as unit is turned on to check filter cleanliness.

Fluid Power Systems Maintenance and Operation

Unit 6: Service Equipment

LESSON 1: HYDRAULIC FILTER BUGGY

Interaction Items: (Review Items)

1. Discuss contaminant generation when component failure occurs.
2. Discuss why oil must be kept clean.
3. Discuss how fresh drum oil can be contaminated.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 1: HYDRAULIC FILTER BUGGY

Evaluation Items:

1. List the equipment contained on a hydraulic filter buggy.

   a.

   b.

   c.

   d.

2. List four uses of a filter buggy.

   a.

   b.

   c.

   d.

3.1 What micron rated filter should be used on a filter buggy?

3.2 When should filter(s) be changed?

   a.

   b.

3.3 Why should care be exercised when changing filters?

4. Before using a filter buggy, what steps should be taken to prevent contamination?

   a.

   b.

LESSON 1: HYDRAULIC FILTER BUGGY

Answers to Evaluation Items:

1. a. Pump
   b. Pre-strainer
   c. 3-micron filter
   d. Electric motor

2. a. Fill hydraulic units with new oil
   b. Clean up fluid after component failure
   c. Auxiliary filtration
   d. Transfer pump

3.1 3-micron

3.2 a. When dirt indicator says so
   b. When type of fluid is changed

3.3 Allowing dirt to enter system

4. a. Clean hose
   b. Change filter in cross contamination of oil will occur

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

Scope of the Unit: After completion of this unit, the student will be familiar with some of the more recent developments and ideas that are being applied to the field of fluid power. This unit will introduce 1) energy requirements and savings, 2) module and cartridge valve assemblies, 3) proportional valves, and 4) programmable controls. The student should be able to discuss these ideas and score 85% on the evaluation items.

LESSON 1: ENERGY REQUIREMENTS AND SAVINGS FOR HYDRAULIC PUMPS

Lesson Objectives - the student should be able to:

1. Calculate cost to operate a fixed displacement pump.
2. Calculate heat generated by oil flowing over a relief valve.
3. Calculate cost to operate a pressure compensated pump.
4. Select, based on pressure and flow requirements, the type of pump to be used.
5. Calculate payback period for an energy efficient electric motor.
6. Define a constant horsepower control.

Supplementary Learning/Teaching Items:

Informational Assignment:

References: (Instructor's Additional Information)

Introduction: Since the mid-1970's, most companies have become conscious of energy costs and have made an effort to reduce them. This lesson will introduce some methods of reducing the cost of energy used by a hydraulic system.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 1: ENERGY REQUIREMENTS AND SAVINGS FOR HYDRAULIC PUMPS

Outline: (Key Points)

I. Power Requirement - Fixed Displacement Pump

A. Fixed displacement pumps deliver a fixed volume of fluid at a constant RPM regardless of system pressure

B. Horsepower requirement

$$HP = \frac{GPM \times PSI}{1714 \times Eff}$$

Where GPM = Gallons per minute being pumped

$$GPM = \frac{Disp \times RPM}{}$$

PSI = Pressure at pump outlet in psi

Disp = Pump displacement in in^3/REV

HP = Horsepower

Eff = Pump Efficiency

Example #1: A 2.0 in^3 fixed diplacement pump, 96% eff, operating at 1800 RPM and 3000 psi.

$$GPM = \frac{(Disp)(RPM)}{231} = \frac{(2.0)(1800)}{231} = 15.6 \text{ GPM}$$

$$HP = \frac{(GPM)(PSI)}{(1714)(Eff)} = \frac{(2.0)(3000)}{(1714)(.96)} = 28.5 \text{ Horsepower required to drive pump}$$

C. Cost to operate pump - Example #2

1 HP = 746 watts 1000 watts = 1 kilowatt

If electricity cost \$0.06 per kilowatt-hour

$$Cost = \frac{HP \times 746 \times Cost/kw\text{-}hr}{1000} = \frac{(28.5)(746)(.06)}{1000} = \$1.16 \text{ per hour}$$

Therefore, it will cost \$1.16 per hour to drive pump if electric motor is 100% efficient.

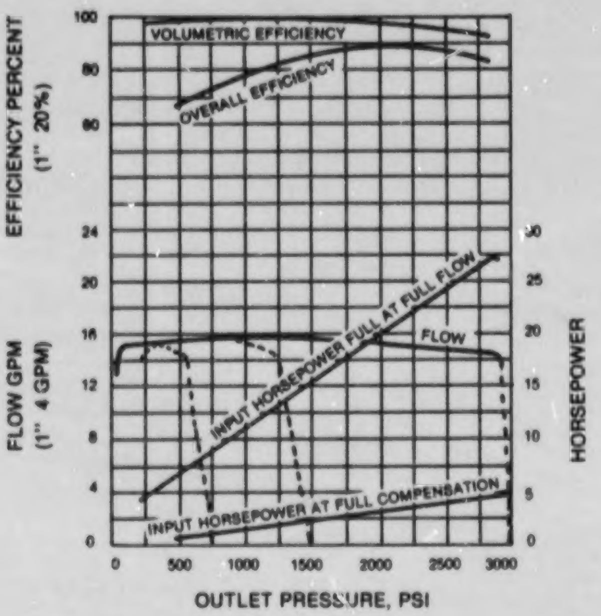
II. Power Requirements - Variable Displacement Pressure Compensated Pump

A. A variable displacement pump with pressure compensation will deliver maximum volume until pressure of system reaches the value of the pressure compensator setting; at that point the pump will destroke to the fully compensated position or to the position required to maintain system pressure.

B. Horsepower requirement at full volume - same as fixed displacement. See section I.

C. Horsepower requirement at compensation - The power required at compensation is less because the pump has to draw only the power required to pump internal leak oil and overcome internal friction. Compensated horsepower is determined by the pump manufacturer and supplied in their sales information.

Example #2: See graph and chart for Parker PAVC 33 below.



MODEL NUMBER	THEORETICAL DISPLACEMENT CU. IN/REV. (CC/REV.)	DELIVERY GPM (LITER/MIN.) AT 300 PSI & 1200 RPM	1800 RPM	2500 RPM	APPROXIMATE GPM @ MAX. SPEED & 2800 PSI	APPROX. INPUT HP @ 3000 RPM & 2800 PSI
PAVC 33	2.0 (33)	10 (38)	15 (57)	21 (87)	26 (98)	45

For the same requirements as the pump used in section I, this pump would use 15.6 HP at full volume, the same as fixed displacement. This pump would require 5 HP at compensation.

Example #3: Cost at compensation

$$\frac{\text{HP} \times 746 \times \text{Cost/kw-hr}}{1000} = \frac{(5)(746)(.06)}{1000} = \$0.22 \text{ per hour}$$

Cost saving at compensation over the fixed displacement point:

$1.16 - $.22 = $.94 per hour cost saving

III. Heat Generation

A. Heat is measured in British thermal units (BTU). One BTU is the quantity of heat required to raise the temperature of one pound of pure water one degree fahrenheit.

B. Oil moving across a relief valve converts pressure into heat.

C. 1 Horsepower = 2545 BTU per hour

D. The amount of heat generated by oil exhausting over a relief valve is

$$\text{Heat generated} = \frac{(\text{GPM})(\text{PSI})(2545)}{1714}$$

Example #4: If pump used in Example #1 was deadheaded and exhausting its total flow over a relief valve set at 3000 psi, the quantity of heat being generated would be:

$$\text{Heat generated} = \frac{(\text{GPM})(\text{PSI})(2545)}{1714} = \frac{(15.6)(3000)(2545)}{1714}$$

$$= 69490 \text{ BTU per hour}$$

This heat would have to be removed by use of cooling equipment.

IV. Choice of pumps for energy efficient use is a function of amount of oil required at any given time.

A. If full flow is required most or all of the time a fixed displacement pump may be acceptable.

B. When full flow is required only part of the time and the remainder of the time is at zero (0) flow and pressure, a fixed displacement pump could be used if it is unloaded during zero flow and pressure time period.

C. If full flow is required only part of the time and the remainder of the flow required is less but system pressure has to be maintained, a pressure compensated pump should be used to save:

1) Energy - Less horsepower is required at compensation than by

pumping over a relief valve as a fixed displacement pump would.

2) Heat generation - A pressure compensated pump would not generate heat by pushing oil over a relief valve. The only heat generated is from internal pump leakage and friction.

D. If full flow is required only part of the time and the remainder of the time the flow required is zero (0) but system pressure has to be maintained, then two choices are available:

1) Pressure compensated pump

2) Fixed displacement pump that can be unloaded (when flow is not required) and an accumulator to maintain system pressure during this time

V. Energy Efficient Electric Motors

Operating time: A hydraulic system that will be operated at or near full load for long periods of time can make good use of energy efficient electric motors.

A. Energy efficient motors use approximately 5% less power (on small HP motors) to 1% less for very large motors. If the system is in operation most of the time, an energy efficient motor can produce a cost savings even though it carries a higher purchase price.

NOTE: An energy efficient motor will not produce a savings if NOT operated at or near full load.

B. Payback period for energy efficient motors

1) $\text{Watts saved} = \text{HP} \times 746 \times (\Delta_{\text{eff}})$

Where: HP = Horsepower of motor

Δ_{eff} = Difference of efficiency between an energy efficient motor and an average motor

2) Hours required to payback price difference between energy efficient and average motor

$$\text{Hours} = \frac{(\Delta \$)(1000)}{(\$K)(\text{Watts saved})}$$

Where: $\Delta \$$ = Difference in cost (in dollars) between energy efficient and average motor

$\$ K$ = Cost (in dollars) per kilowatt-hour of electricity

Watts saved = Value from equation above

Example #5: A 15 HP energy efficient motor (91% eff.) vs. an average motor (87% eff.) operating at full load will (if electricity costs $0.06 per kilowatt-hour and the energy efficient motor cost $100.00 more) start to produce a dollar savings after what period of time?

Δ eff = 91 - 87 = 4% difference = .04

Watts saved = (HP)(746)(Δeff) = (15)(746)(.04) = 447.6 watts per hour

$$\text{Hours} = \frac{(\Delta \$)(1000)}{(\$K)(\text{watts saved})} = \frac{(100)(1000)}{(.06)(447.6)} = 3724 \text{ hours}$$

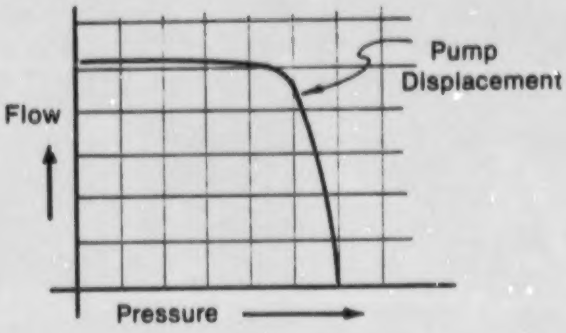
If a work year is 4000 hours (8 hours per shift, 2 shifts per day, 5 days per week, 50 weeks per year), payback on this energy efficient motor is 3724 ÷ 4000 = 0.93 years*

* Not taking into account interest on the $100.00 price difference.

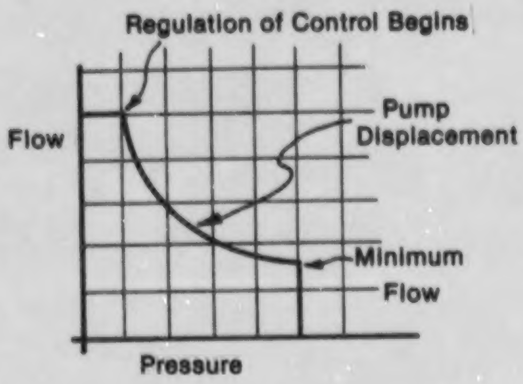
VI. Variable Displacement Pump with Constant Horsepower Control: A constant horsepower control is used to keep the prime mover (constant speed type, such as an electric motor or an internal combustion engine with a RPM governor) operating at a constant horsepower level. For a pump to consume a constant horsepower from the prime mover, the pump must maintain the product of pressure x flow at a constant value. This means that as the pressure in the system increases, the flow will decrease.

A constant horsepower control senses the load induced pressure in the system and changes pump flow accordingly to maintain a constant required horsepower.

Graph of variable displacement pump with pressure compensator control



Graph of variable displacement pump with constant horsepower control



Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 1: ENERGY REQUIREMENTS AND SAVINGS FOR HYDRAULIC PUMPS

Interaction Items: (Review Items)

1. Work an example problem using the same circuit but different type pumps to show energy cost.
2. Work the same problem as #1 above but use an accumulator to hold pressure.
3. Discuss energy saving ideas that the student could put to use.

Classroom, Laboratory, Shop or Other Activities:

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 1: ENERGY REQUIREMENTS AND SAVINGS FOR HYDRAULIC PUMPS

Evaluation Items:

Using the equations from the information outline, work the following problems.

1. What is the cost to operate a 4.0 in^3 fixed displacement pump of 95% eff at 2500 psi for 1 work year (4000 hours) if a 1750 RPM electric motor is used as the prime mover? Electricity cost is $0.055 per kilowatt-hour.

2. If the pump in problem #1 dumps 100% of its flow over a relief valve, how many BTU's would a heat exchanger have to remove to hold the oil temperature constant?

3. How much money could be saved in one year by using a pressure compensated pump as discussed in Problem 1 instead of a fixed displacement pump? Assume that the pressure compensated pump compensates at 8 HP and is in the compensated mode 35% of the time.

4. What type of pump could be used if the flow required is:

   a. Full flow all of the time?

   b. Full flow part of the time and no flow or pressure remainder of the time?

   c. Full flow part of the time, 1/2 flow at full pressure remainder of the time?

   d. Full flow at maximum pressure or no flow at maximum pressure?

5. What is the payback period of a 50 HP energy efficient motor?

   Average motor - 91% eff Energy efficient motor - 93% eff

   Work year is 4000 hours; Electricity cost is $0.055/kilowatt-hour; Premium paid for efficient motor is $250.00

6. What does a constant horsepower control do?

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 1: ENERGY REQUIREMENTS AND SAVINGS FOR HYDRAULIC PUMPS

Answers to Evaluation Items:

1. $$\text{GPM} = \frac{(4)(1750)}{251} = 30.3 \text{ GPM}$$

$$\text{HP} = \frac{(30.3)(2500)}{(1714)(.95)} = 46.53 \text{ HP}$$

$$\text{Cost/Hr} = \frac{(46.53)(746)(.055)}{1000} = \$1.909/\text{Hr}$$

2. $$\text{Heat generated} = \frac{(30.3)(2500)(2545)}{1714} = 112{,}476 \text{ BTU/Hr}$$

3. 46.53 - 8 = 38.53 HP Saved during compensation

Time spent at compensation = (4000)(.35) = 1400 hours

$$\text{Cost/Hr} = \frac{(38.53)(746)(.055)}{1000} = \$1.58/\text{Hr less}$$

Cost saving = (1.58)(1400) = $2,213.24/Year

4.
   - a. Fixed displacement
   - b. Fixed displacement pump with unloading valves
   - c. Pressure compensated pump
   - d.
     1. Pressure compensated pump
     2. Fixed pump with unloading valve and accumulator in circuit to hold pressure

5. $\triangle$ eff. = 93 - 91 = 2% = .02

Watts saved = (50)(746)(.02) = 746

$$\text{Hours} = \frac{(250)(1000)}{(.055)(746)} = 6093$$

$$\frac{6093}{4000} = 1.52 \text{ years to pay back}$$

6. Control varies pump flow as system pressure changes to maintain a constant horsepower at pump input shaft.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 2: MODULE VALVE ASSEMBLIES AND CARTRIDGE VALVES

Lesson Objectives - the student should be able to:

1. Discuss the advantages and disadvantages of manifold block assemblies.

2.1 Identify the parts of a cartridge insert valve.

2.2 Discuss the advantages and disadvantages of cartridge insert valves.

2.3. Discuss what cartridge valve ratio means.

2.4. Explain how cartridge valves operate.

3. Identify the graphic symbols for different types of cartridge valves.

Supplementary Learning/Teaching Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Manufacturer's catalogs and information bulletins

Introduction: As fluid power systems become larger and more complicated, conventional valves and piping systems become prohibitively expensive. Module and cartridge valve assemblies offer a solution to this problem.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 2: MODULE VALVE ASSEMBLIES AND CARTRIDGE VALVES

Outline: (Key Points)

I. Module mounted assemblies: Module assemblies are blocks that have been machined to incorporate one (1) or more valve mounting surfaces and their interconnecting passages.

These blocks can be bolted together to form complete hydraulic system assemblies.

The valves used may be of conventional design or special design.

A. Advantages of manifold assemblies:

1. System can be assembled in less time than systems using pipe and tube.
2. Less chance of leaks by eliminating tube and pipe fittings
3. Components can be changed easily as with subplated mounted equipment.
4. Manifold block construction lessens the chance of mistakes being made during piping.
5. Lower pressure drop through system
6. Lower individual component cost in some cases

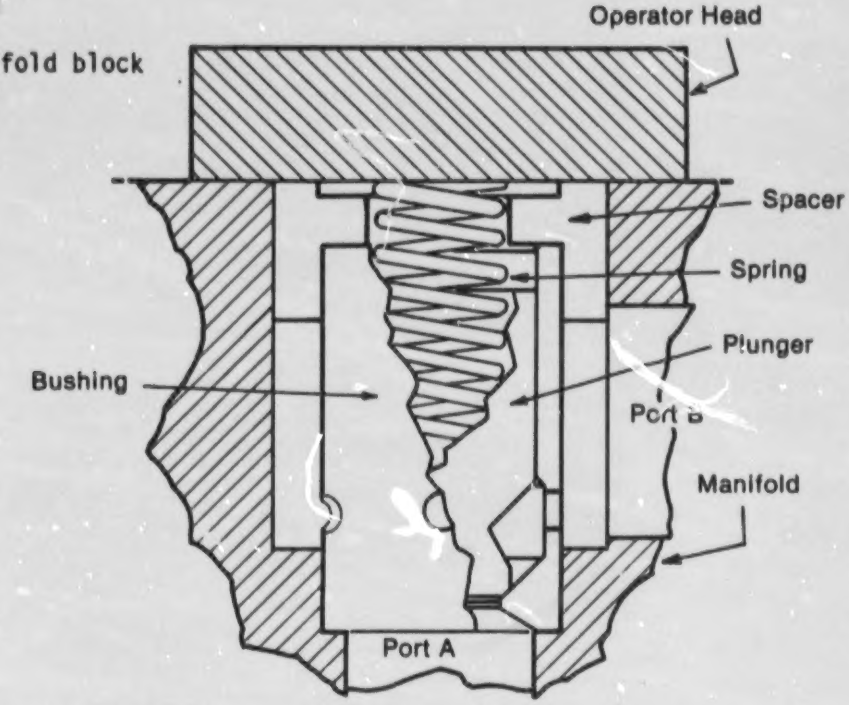
B. Disadvantages of manifold assemblies:

1. Costly to design for one-of-a-kind systems
2. Cost of manifold block may be prohibitive.
3. Changes to system may be difficult to make.
4. Some parts may not be interchangeable among different systems.

II. Cartridge insert valves - A cartridge insert valve consists of:

1) Bushing
2) Plunger
3) Spacer/spring assembly
4) Operator head

Mounted in a manifold block



A. Advantages of cartridge valves

1. System can be assembled in less time than systems using pipe and tube.
2. Less chance of leaks by eliminating tube and pipe fittings
3. Faulty valve can be changed easily.
4. Cartridge block design lessens the chance of mistakes being made in piping.
5. Lower pressure drop than conventional system design due to streamlined flow through valve.
6. Lower individual component cost in some cases.

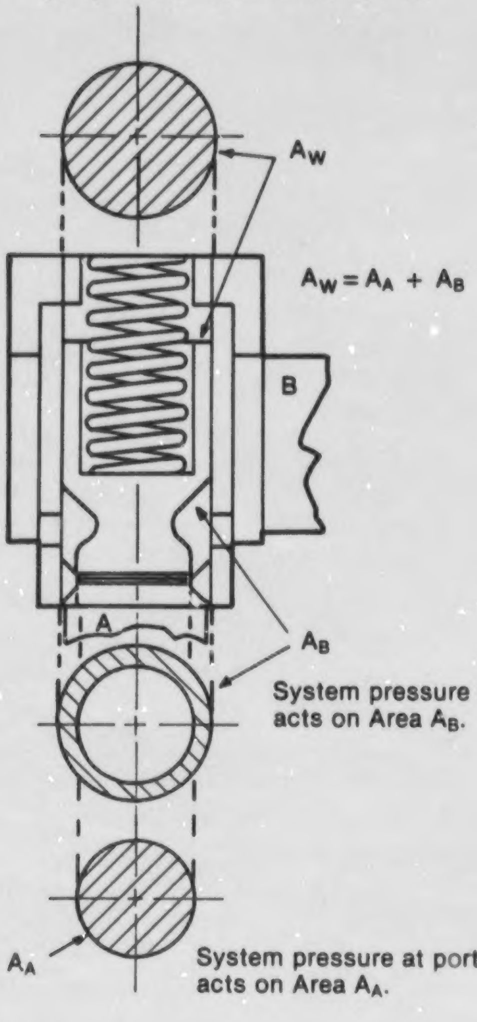
7. Poppet type seat minimizes leakage across valve.

8. Large flow rates are possible (up to 1000 GPM).

B. Disadvantages of cartridge valve

1. Mounting blocks can be costly to design and build.
2. Changes to system may be difficult to make once block is machined.

C. Cartridge ratios - Opening and closing of the valve is a function of fluid pressure acting on three areas, A_A, A_B, and A_W.



Pilot Control Pressure plus Spring Force acts on full area Aw.

System pressure at port B acts on Area A_B.

System pressure at port A acts on Area A_A.

1. Pressure acting on A_A and A_B (when applicable) tends to open the plunger.

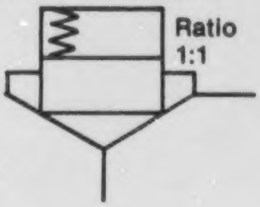
2. Pilot pressure acting on A_W (when applied) plus spring force tend to close plunger.

Area A_A is always considered 1 or unity
Area A_W is the sum of $A_A + A_B$

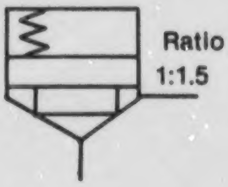
Example: A ratio of 1:1.5 (1 to 1.5) is

$$A_A = 1 \qquad A_A + A_B = A_W = 1.5$$

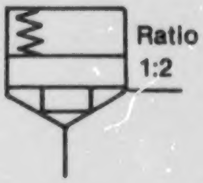
GRAPHIC SYMBOL



GRAPHIC SYMBOL



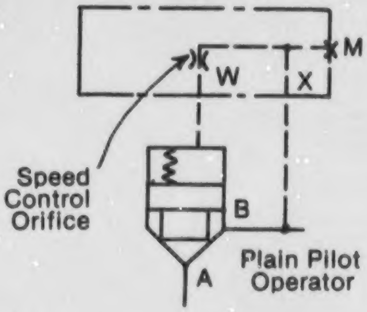
GRAPHIC SYMBOL



D. Cartridge valve operators - The operator head supplies pilot pressure to (or removes it by draining) the spring chamber area (A_W) of the valve.

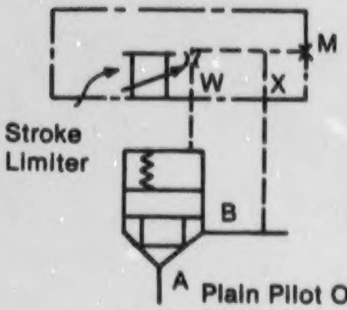
The plunger will remain closed (or will close) when the pilot pressure x A_W = spring force is greater than the force from A_A + A_B.

GRAPHIC SYMBOL


M
W
X
Speed
Control
Orifice
B
A
Plain Pilot
Operator

A stroke limiter can be added to the pilot section to limit the amount of travel of the plunger. This will allow control of the quantity of oil flow through the valve.

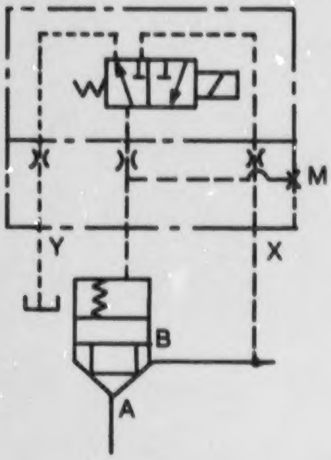
GRAPHIC SYMBOL



Plain Pilot Operator with Stroke Limiter

Electrical solenoids can be added to the operator head to electrically operate a separate plunger or ball check valve for remote control of the main plunger.

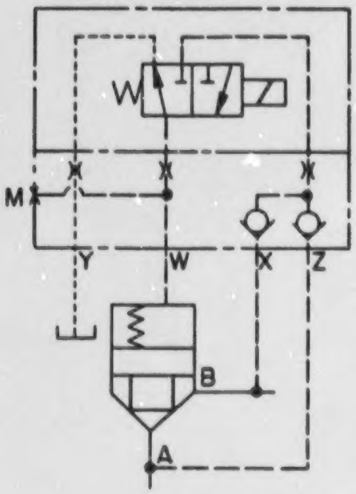
GRAPHIC SYMBOL



With solenoid de-energized, the spring chamber is drained through Port Y, allowing flow from Port A to B, or B to A whenever spring force can be overcome. With solenoid energized, pressure from Port B is applied to area A_A. Flow from B to A is blocked, but flow from A to B can occur if pressure at A is great enough to overcome pressure at B and spring force.

Solenoid pilots with dual checks can be added to force cartridge valve to act as a two-way valve.

GRAPHIC SYMBOL

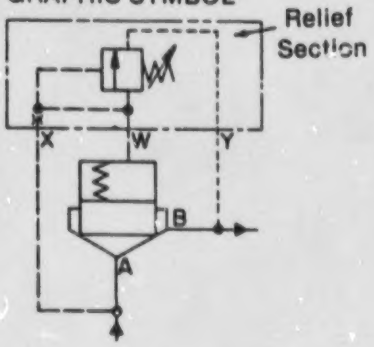


Solenoid Pilot Operator with Dual Checks

With solenoid de-energized, this valve operates in the same manner as a cartridge valve without checks. When solenoid is energized, pressure for either Port A or B (whichever is greater) is connected to area A_W causes the plunger to be closed.

E. Pressure regulating operators. By mounting a small pilot operated relief section to the operator head a cartridge valve can be made to perform as a relief valve.

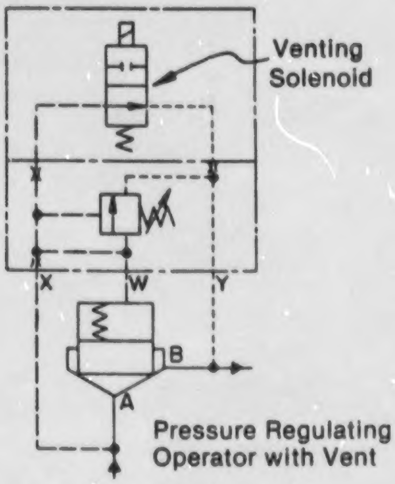
GRAPHIC SYMBOL



Pressure Regulating Operator

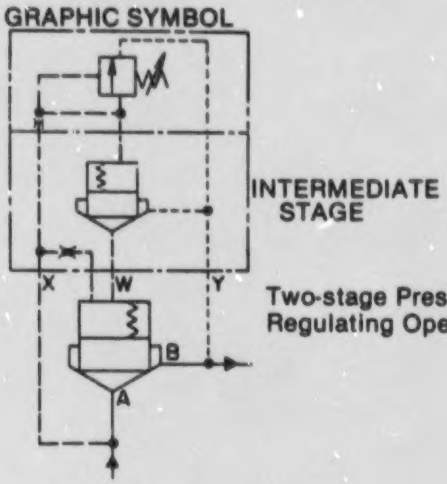
This relief valve cartridge assembly can be vented to act as an unloading valve by the addition of a small solenoid operator in the head to vent the A_W cavity when the solenoid is de-energized, allowing free flow from A to B, as long as the light spring force can be overcome.

GRAPHIC SYMBOL



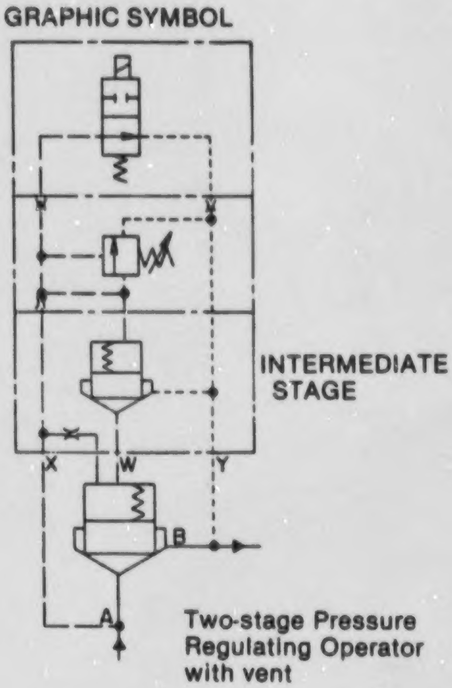
Pressure Regulating Operator with Vent

For very large flow requirements, a small cartridge valve (intermediate stage) can be used to control a larger size cartridge valve.


GRAPHIC SYMBOL
INTERMEDIATE STAGE
X
W
Y
B
A

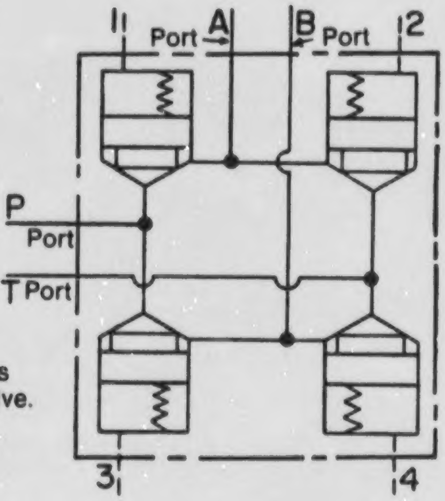
Two-stage Pressure Regulating Operator

Note: size difference to imply two different size cartridges


GRAPHIC SYMBOL
INTERMEDIATE STAGE
X
W
Y
B
A

Two-stage Pressure Regulating Operator with vent

F. Directional control valves: By arranging four or more cartridge valves, a four-way directional control valve can be produced.


1
Port A
B Port
2
P Port
T Port
3
4

Four Pilot Operated Cartridges inseat valves arranged as a 4-way valve.

By applying pilot oil at ports 1, 2, 3, and 4 in the correct sequence, this valve package can be made to "shift" as a normal four-way valve would.

The "center" condition is determined by which cartridges are energized. Tandem (requires five cartridges), open center, motor spool, closed and many others can be duplicated.

For design and troubleshooting of such a four-way valve package, refer to manufacturer's catalog for logic chart.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 2: MODULE VALVE ASSEMBLIES AND CARTRIDGE VALVES

Interaction Items: (Review Items)

1. Discuss design considerations for choosing module blocks and cartridge valves.
2. Show and discuss logic chart for cartridge valves used as a four-way valve.
3. Show pressure drop of cartridge valves vs. conventional four-way valve.
4. Discuss layout and machining of manifold blocks and cartridge blocks.

Classroom, Laboratory, Shop, or Other Activities:

Show examples of manufacturer's catalogs and hardware.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 2: MODULE VALVE ASSEMBLIES AND CARTRIDGE VALVES

Evaluation Items:

1. Discuss advantages and disadvantages of manifold block assemblies.

2.1. Identify the parts of a cartridge insert valve.

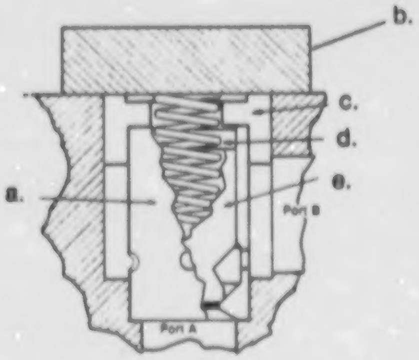
a.

b.

c.

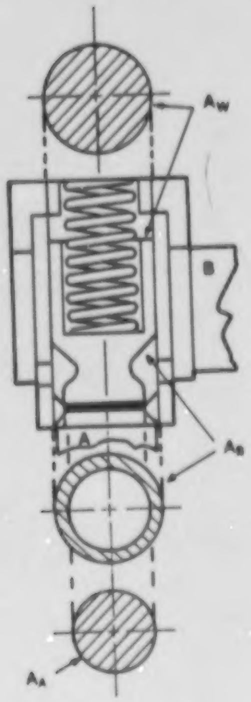
d.

e.



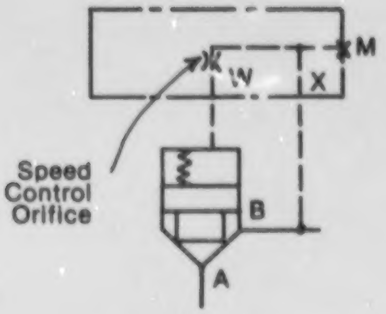
2.2. Discuss advantages and disadvantages of cartridge insert valves.

2.3 Explain how a cartridge valve operates.

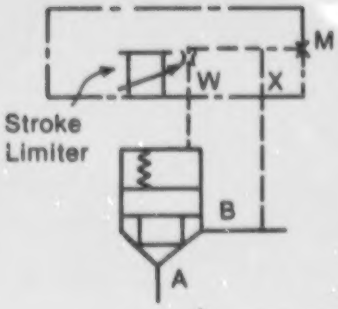


2.4. Discuss what a ratio of 1:2 on a cartridge valve means.

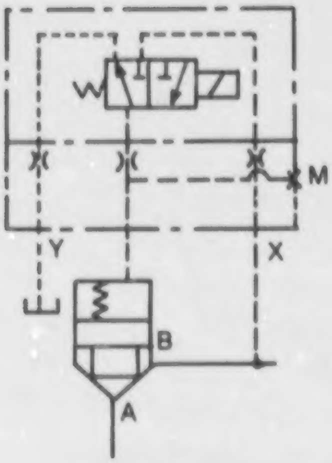
3. Identify the following cartridge valve symbols.


M
W
X
Speed Control Orifice
B
A

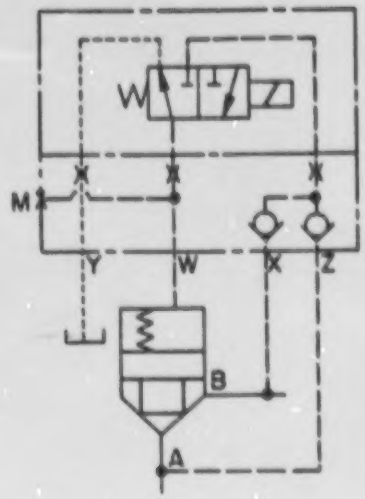
a. ______________________


M
W
X
Stroke Limiter
B
A

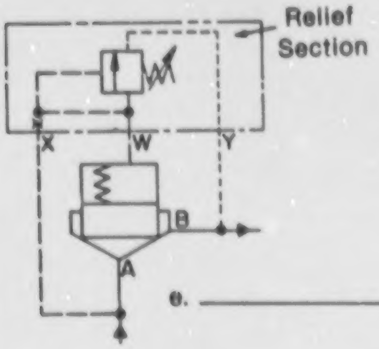
b. ______________________



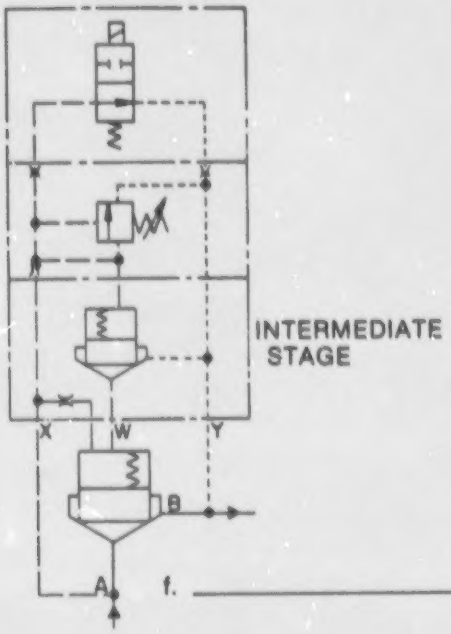
c. ______________________



d. ______________________


Relief Section
X
W
Y
B
A

e. ______________________


INTERMEDIATE STAGE
X
W
Y
B
A

f. ______________________

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 2: MODULE VALVE ASSEMBLIES AND CARTRIDGE VALVES

Answers to Evaluation Items:

1. Answer should include five advantages and disadvantages from section #I.

2.1. a. Bushing
  b. Operator head
  c. Spacer
  d. Spring
  e. Plunger

2.2. Answer should include seven advantages and the disadvantages listed in II A and B.

2.3. a. Pressure acting on A_A and A_B open plunger
  b. Pilot pressure acting on A_W plus spring close plunger

2.4. $A_A = 1$ $A_A + A_B = A_W = 2$

3. a. Plain pilot operator cartridge valve
  b. Pilot operator with stroke limiter
  c. Solenoid pilot operator
  d. Solenoid pilot operator and dual checks
  e. Pressure regulating operator
  f. Two stage regulator with vent

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 3: PROPORTIONAL VALVES

Lesson Objectives - the student should be able to:

1. Define response, bandwidth, deadband, repeatability, threshold hysteresis, and LVDT.
2. List differences between servo and proportional valves.
3. List and explain the major sections of a proportional valve.
4. List and explain the uses of a proportional valve.

Supplementary Learning/Teaching Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

1. Manufacturer's catalogs
2. Book on servo valves (for definitions)

Introduction: Proportional valves may one day replace flow control valves when used in conjunction with a programmable controller. Energy savings on some types of circuits can be substantial.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 3: PROPORTIONAL VALVES

Outline: (Key Points)

I. Introduction and Definitions

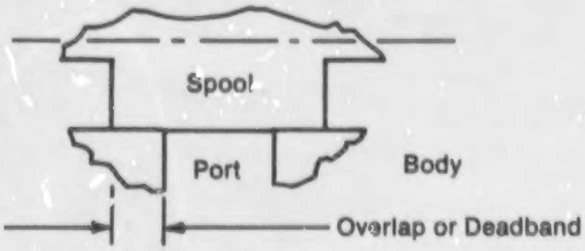
A. Introduction - Proportional valves are similar to servo valves in their operation and use in a circuit. Basically, they are four-way directional control valves with a spool that can be positioned anywhere along the valve's full operating stroke and contains a feedback signal to confirm and/or adjust the spool's position.

B. Definitions

1. Bandwidth - the frequency range to which the valve will respond.

2. Response - a measure of how fast a valve can change output flow in reaction to a change in command signal.

3. Deadband - overlap between the body sealing lands and the spool sealing lands.



4. Repeatability - ability to reposition to the same place time after time, given the same input signal.

5. Threshold - smallest value of control to which the signal valve will respond.

6. Hysteresis - the difference in valve positions for the same input signal, caused by the previous input signal. It is a measure of the memory of the system. (See Figure 2.)

7. LVDT - Linear Variable Differential Transformer

II. Difference Between Proportional Valves and Servo Valves

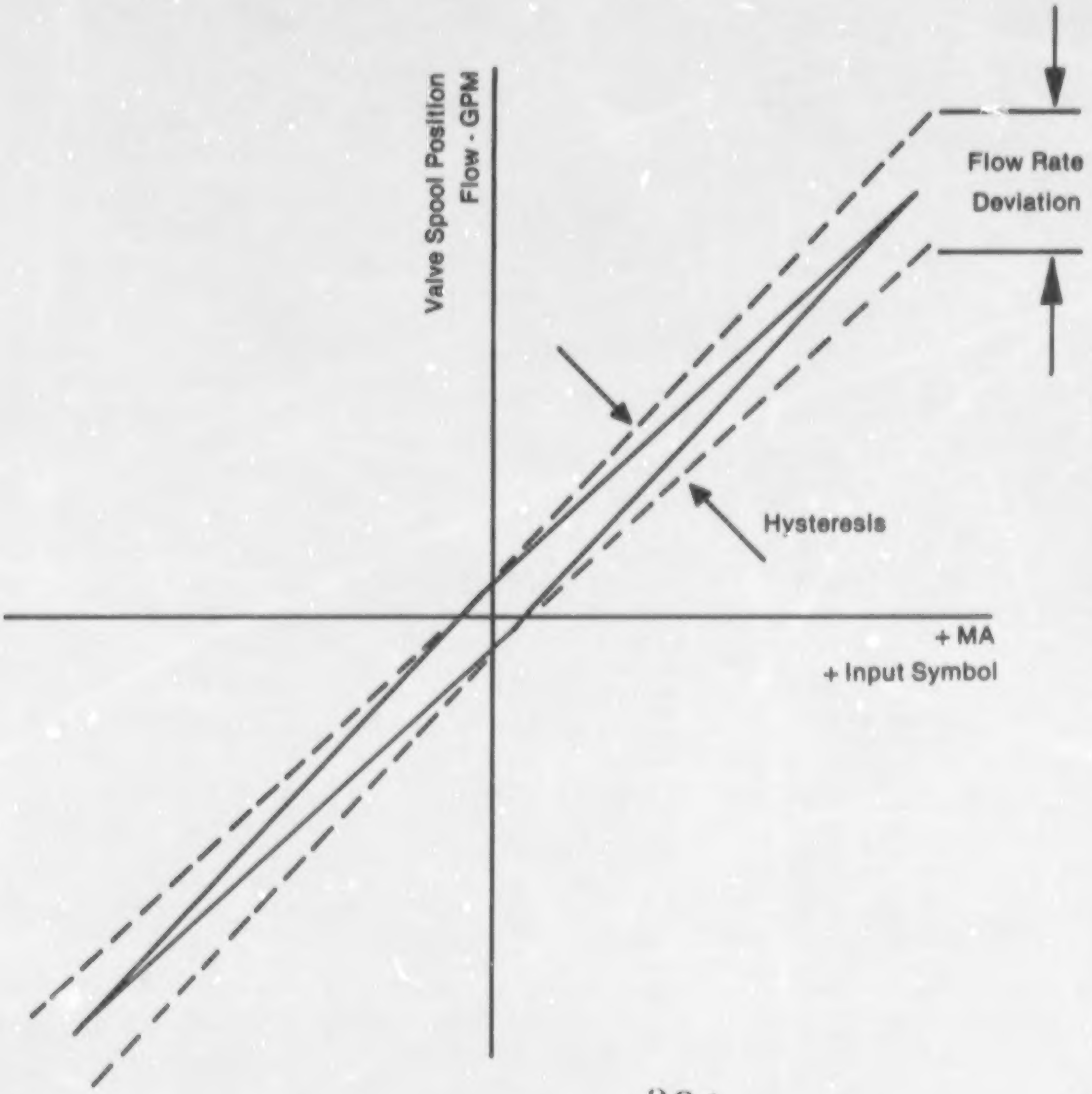
A. Bandwidth - In general, a servo valve will have a wider bandwidth value than a proportional valve.

B. Servo valves are manufactured to close tolerances on spool lands and port opens to produce a carefully matched center condition. Proportional valve spool and bodies are interchangeable so manufacturing tolerance can produce spool crossover overlaps (called deadband) of between 10% to 30% of total spool travel.

C. Proportional valves have higher operating tolerances (less desirable) for hysteresis, threshold, and repeatability than servo valves.

D. Level of required filtration - Servo valves have smaller fluid passages than proportional valves. Where servo valves require filtration below the three micron level, proportional valves will operate satisfactorily at 10 micron filtration.

E. Cost - Proportional valves are less expensive than servo valves.



III. Construction - Proportional valves have three (3) major components - 1) pilot valve, 2) power valve, 3) LVDT section

A. The pilot valve - a four (4) port valve for:

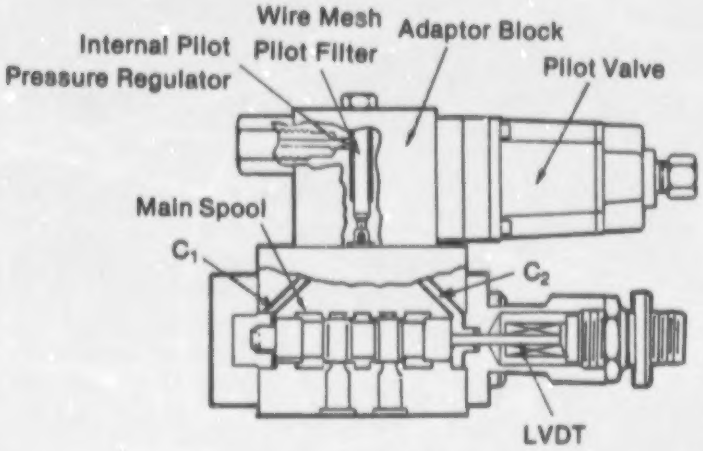
1. Supply oil

2. Return oil

3. C_1 - Control oil from Port #1

4. C_2 - Control oil from Port #2

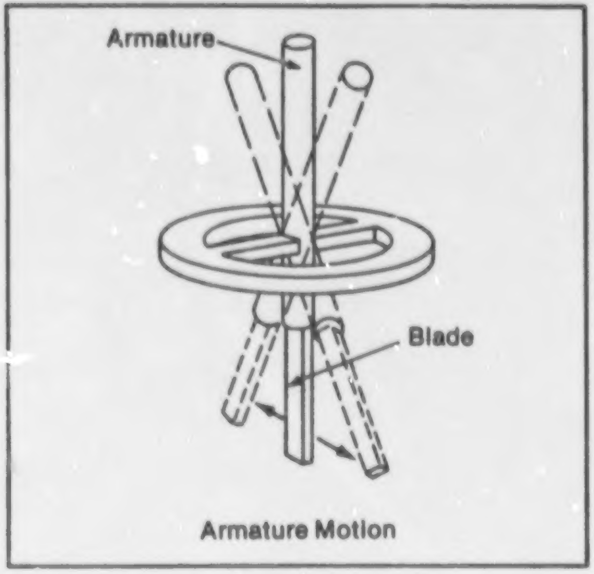
NOTE: C_1 and C_2 are connected to the pilot ends of the power spool.



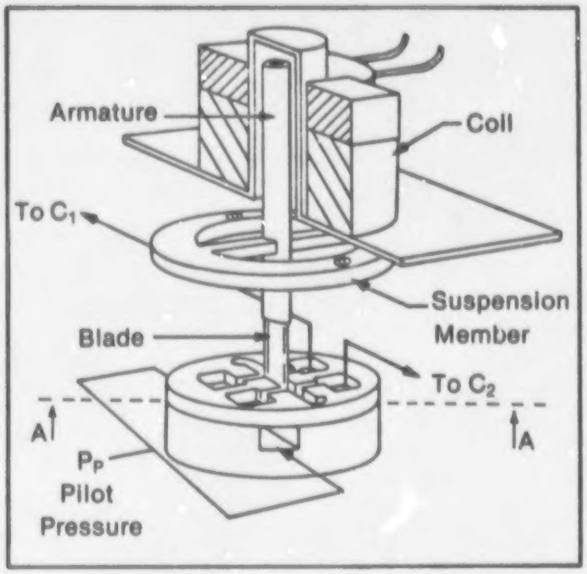
B. Operation of pilot valve - A reversible proportional electrical signal produces a reversible pressure differential between Ports C_1 and C_2 through the armature motion. This differential pressure is used to pilot (move) the power spool. The higher the electrical signal and the larger pressure differential created, the greater the movement of the main spool and the greater the flow of oil through the main valve.

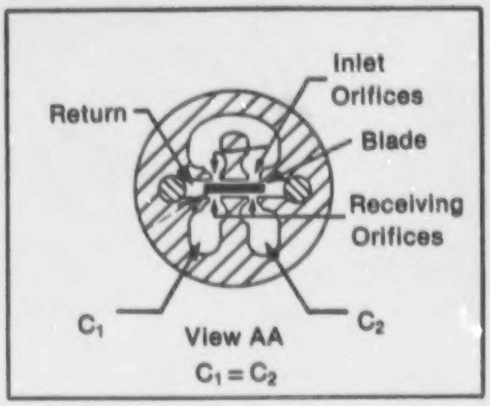
The differential pressure is produced in the pilot valve by an electrical signal transmitted to the pilot valve coil. This coil produces a magnetic field which causes the armature to deflect into the supply flow stream causing flow from the supply ports to be partially or totally blocked at C_1 or C_2, causing a pressure difference between C_1 and C_2.

C. Power valve - The power valve is very similar to a common 4-way spool valve. The spool is shifted by control pressure from C_1 and/or C_2. The major difference is that the spool is tapered at each land end in an attempt to cause a linear increase in flow for a linear amount of spool movement.

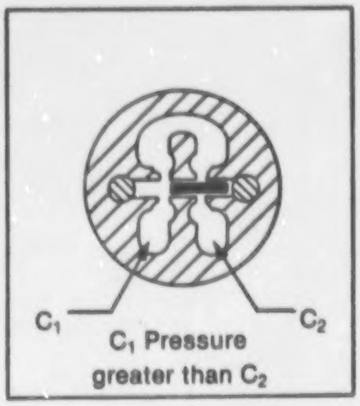

Armature
Blade

Armature Motion

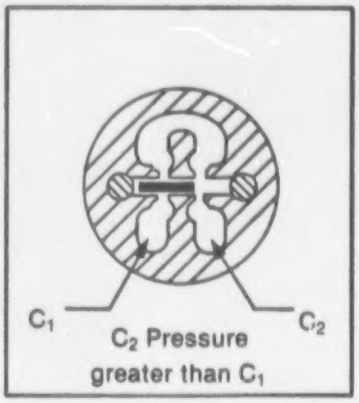

Armature
Coil
To C_1
Suspension Member
Blade
To C_2
A
A
P_P Pilot Pressure


Inlet Orifices
Return
Blade
Receiving Orifices
C_1
C_2

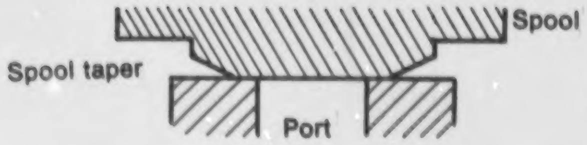
View AA
$C_1 = C_2$



C_1 Pressure greater than C_2

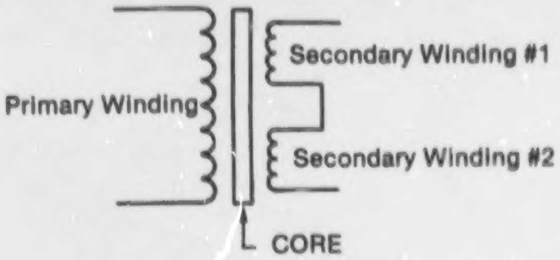


C_2 Pressure greater than C_1



The amount of flow through the valve is a function of pressure drop across the spool opening size. By holding the pressure drop constant, an increase in spool movement will produce a corresponding increase in flow through the valve.

D. LVDT feedback - An LVDT is a moveable core transformer with three sets of windings - a primary winding and two secondary windings in series, one wound clockwise, the other wound counterclockwise. An AC signal is applied to the primary winding, causing an oscillating magnetic field. The moveable iron core acts as a coupling to the secondary windings, allowing the primary windings to induce an electrical current into the secondary windings.



If the core is centered equally in the secondary windings, an equal current is generated in each secondary winding. When the core is moved off center, one winding will generate a higher current.

The LVDT is mechanically attached to the spool, thus giving an electrical indication of the spool's position. This electrical signal is compared to the control signal applied to the armature coil in the pilot valve. If the two are equal, nothing happens, if the LVDT signal is different, then the armature coil signal is increased or decreased until signals do match.

IV. Proportional Valve Uses

A. Variable displacement pump - A variable displacement pump equipped with a load sensing control is a system in which the control adjusts the pump output flow so as to maintain a fixed pressure drop across a valve. If this valve were of the proportional type, an electrical signal supplied to the proportional valve would cause the valve to shift a pre-determined amount. Pump stroke would then increase (or decrease) until the fixed pressure drop was established. Remote control and energy savings are the two major benefits.

B. Controlling speed and direction of actuators - the proportional valve can be used in place of a standard 4-way valve to control the direction of operation of an actuator (linear or rotary). By setting one or more (depending on control system logic) positions for valve movement, the speed of the actuator is controlled without the use of standard flow control valves.

C. Variable acceleration and deceleration of actuators can also be accomplished by controlling the speed at which the proportional valve shifts. Since spool position translates into flow through the valve, actuator acceleration and/or deceleration can be controlled.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 3: PROPORTIONAL VALVES

Interaction Items: (Review Items)

1. Show a proportional valve manufacturer's catalog.
2. Discuss the use of proportional valves in circuits.
3. Discuss energy savings achieved by using proportional valves.

Classroom, Laboratory, Shop, or Other Activities:

If a proportional valve is available, demonstrate its use in an operating circuit.

LESSON 3: PROPORTIONAL VALVES

Evaluation Items:

1. Define:
   a. Response

   b. Bandwidth

   c. Deadband

   d. Repeatability

   e. Threshold

   f. Hysteresis

   g. LVDT

2. List four differences between a servo valve and a proportional valve.
   a.

   b.

   c.

   d.

3. List the three major sections of a proportional valve.

   a.

   b.

   c.

4. Explain how each of the three major sections of a proportional valve operates.

5. List three uses of proportional valves.

   a.

   b.

   c.

6. Explain one use of a proportional valve.

Fluid Power Systems Maintenance and Operation

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LESSON 3: PROPORTIONAL VALVES

Answers to Evaluation:

1. a. Response - a measure of how fast a valve can change output flow in reaction to a change in command signal.
   b. Bandwidth - the frequency range to which the valve will respond.
   c. Deadband - overlap between the body sealing lands and the spool sealing lands.
   d. Repeatability - ability to reposition to the same place time after time, given the same input signal.
   e. Threshold - smallest value of control to which the signal valve will respond.
   f. Hysteresis - the difference in valve positions for the same input signal, caused by the previous input signal. It is a measure the memory of the system. (See Figure 2.)
   g. LVDT - Linear Variable Differential Transformer

2. Any four of these five:

   a. Servo valves have a wider bandwidth than proportional valves.
   b. Servo valves are manufactured to closer tolerances than proportional valves.
   c. Proportional valves have higher operating tolerances for hysteresis, threshold, and repeatability than servo valves.
   d. Servo valves require cleaner operating fluids.
   e. Servo valves cost more.

3. a. Pilot valve
   b. Power valve
   c. LVDT

4.1 Discussion should include explanation of operation from section III - B, C, and D, in the student's own words.

4.2 a. As a remote operated load sensing control.
    b. Controlling speed and direction of actuators.
    c. Controlling acceleration and deceleration of actuators.

4.3 Explain one of the items listed in #5 above. Student's answer should contain information listed in outline section IV.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 4: INTRODUCTION TO PROGRAMMABLE CONTROLS

Lesson Objectives - the student should be able to:

1. Define a programmable control.
2. List major parts of a programmable control, and describe the function of each part.
3. List reasons for using a programmable control system.
4. List uses of a programmable control on a hydraulic system.

Supplementary Learning/Teaching Items:

Informational Assignment: (Student)

References: (Instructor's Additional Information)

Manufacturer's catalogs

Introduction: Programmable controllers, when correctly applied, installed, and programmed, offer the user many advantages. This type of control offers the designer reliability, long life, flexibility, and lower cost.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 4: INTRODUCTION TO PROGRAMMABLE CONTROLS

Outline: (Key Points)

I. Programmable controllers are software-based equivalents of hardwired relay logic control panels, used to electrically control a machine or process. They are composed of the following major components.

   A. Input interface (or input module)

   B. Output interface (or output module)

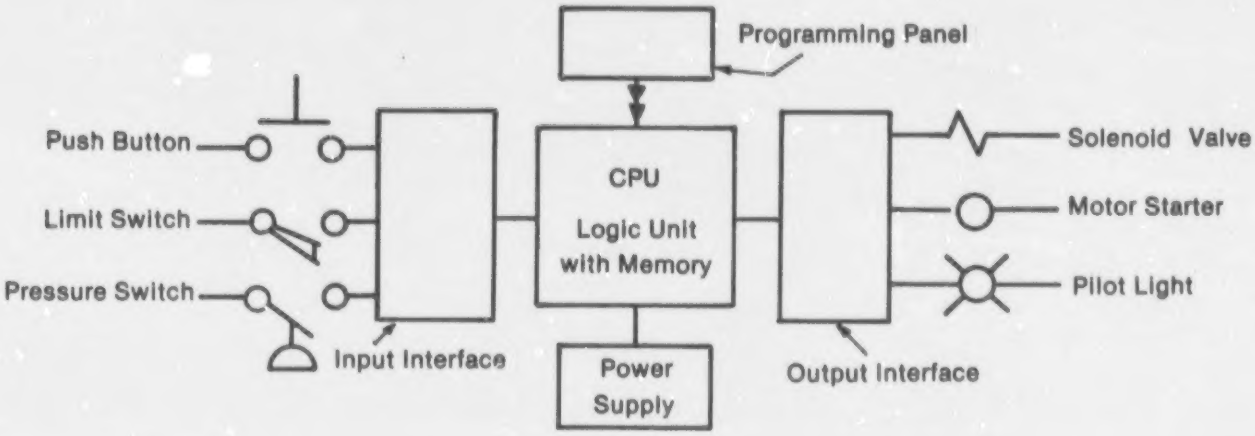
   C. Logic processor unit with memory storage (CPU)

   D. Power supply

   E. Programming device (or memory loader) as either

      1. Integral part of unit, or

      2. Separate part of control that can be detached and used on units of the same kind.


Programming Panel
Push Button
Limit Switch
Pressure Switch
Input Interface
CPU
Logic Unit
with Memory
Power
Supply
Output Interface
Solenoid Valve
Motor Starter
Pilot Light

II. Components

   A. Input interface - This component (hardwired to the machine) receives signals (or commands) from the machine in one of two forms

      1. Digital signals - On/off, closed/open; Examples: Push buttons, limit switches, position encoders

2. Analog signal - a variable voltage signal, Example: An LVDT used as a position indicator, thermocouples for temperature, strain gauges used as pressure sensors.

   NOTE: When input analog signals are used, a special interface card is required to digitize the signal before it can be processed.

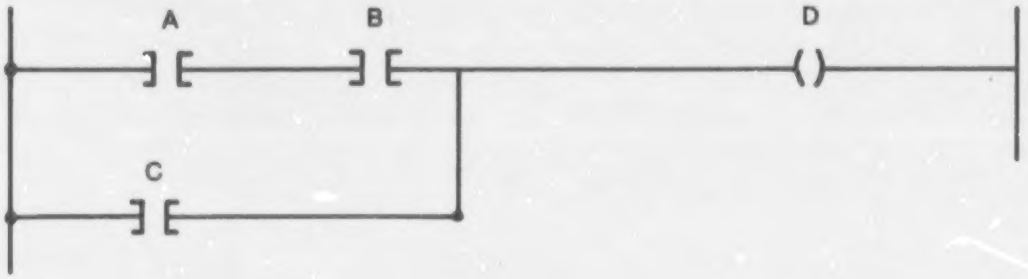
B. Output interface - This component (hardwired to machine) sends control signals (or commands) to the machine in one of two forms

1. Digital signal - on/off; Examples: Light a lamp, turn on a motor, energize a solenoid valve.

2. Analog signal - a variable voltage signal; Example: Variable signal to drive a proportional hydraulic valve.

   NOTE: When analog output signals are required, a special interface card is needed to convert the internal logic processor digital signal to a usable analog output signal

C. Logic processor unit - The processor is often called the CPU or Central Processing Unit. This is the working unit of the programmable controller. The processor's task is to analyze (coordinate) the input data (from the input interface) with the instructions that have been programmed in the memory. When the correct (preprogrammed) conditions are true the CPU will command the output interface to send a signal to the appropriate machine component. An example of how the CPU executes a series of instructions is shown below.



(1) The CPU will scan the input interfaces to determine the status of A, B, and C.

(2) From the program logic, if input A and input B, or if input C is true, the CPU will turn on output interface D.

(3) The CPU will continue to scan the input interface and act on changing input in the manner determined by the program.

1. The CPU has memory storage capabilities. The memory is programmed (into the CPU) by:

   a. The original equipment manufacturer, or

   b. The end user of the programmable controller

2. The program stored in the memory tells the CPU what to do. It is the logic of the programmable control. Most programmable controllers use one of the following types of memories:

   a. Core - Computer Type Ferrite Bead where information is stored magnetically on a ferrite bead in one of two opposing conditions, condition one as 0; condition two as 1. This is older style hardware with limited use capability. Physical size is larger than other types listed.

   b. RAM (Random Access Memory) - information is stored in a solid state chip. This information is held by supplying a constant electrical supply. Battery backup is required in case of power failure to the control so memory storage is retained. This is the most common type in use today.

   c. PROM (Programmable Read Only Memory) - PROMs are solid state chips with information permanently stored in them. These chips do not require electrical power to maintain memory. Normally these chips are not reprogrammable.

3. All three types of memories have the following items in common:

   a. They store the fixed format instructions. The fixed format is the instructions the programmable control requires to be programmed.

   b. Program information is read sequentially, one instruction at a time, line by line. The time required to read (scan) the memory one time is called Memory Scan Time.

   c. One instruction usually takes one unit of memory.

   d. Total memory capacity is the maximum number of instructions or data which the memory can store

D. Power supply - The power supply converts alternating current (60 Hz) into the direct current that the processor unit needs for operation. A typical power supply will convert 110V 60Hz AC into +5 and +15 V DC. Each programmable controller has its own power supply to meet its own specific voltage and current requirements.

E. Programming Device - The programming device or memory loader is the keyboard that is used to program the memory with the user program. The process of "loading" information into the memory varies, depending on the type and manufacturer of the equipment.

1. The programming device can be a separate unit which plugs into the CPU when programming is required, or one that is built into the controller as an integral part. Programmable control programs can also be stored on magnetic cassette tape and down loaded into the CPU via a portable tape recorder.

2. Separate programming devices are desirable if more than one programmable control is in use, as one programming device can be used on a number of P.C.'s that are identical. This not only lowers cost but restricts program access to unauthorized personnel.

III. Reasons For Using Programmable Controllers

A. Replaces relay logic type controls based on reduction in cost because:

1. Less time is required to install system.

2. Changes can be made quickly by reprogramming. An entire new program can be added by loading memory with information stored on magnetic cassette tape.

3. Lower component cost than hardwired systems of similar capabilities.

4. Less floor space is required.

B. Replaces electromechanical timers and counters with solid state components for increased reliability.

C. Some units can perform arithmetic operations if required.

D. Some units can perform information handling operations.

E. Equipment contains self-diagnostics to perform its own troubleshooting.

F. Modular construction allows repair by replacement of subassemblies.

G. High reliability

H. Programmable controls can be linked together and tied to central control

I. Computer compatible

IV. Programmable controllers can be used to control an entire machine or just one part of it such as:

A. Control of a hydraulic pump servo system

B. Control of a hydraulic proportional valve

c. Interface a hydraulic proportional valve with a "smart" cylinder.

Fluid Power Systems Maintenance and Operation

Unit 7: Current System Trends

LESSON 4: INTRODUCTION TO PROGRAMMABLE CONTROLS

Interaction Items: (Review Items)

1. Discuss programmable controller use on equipment with which student is familiar.
2. Show programming of a programmable controller.
3. Demonstrate self-diagnostics capability of capability of programmable control.

Classroom, Laboratory, Shop, or Other Activities:

LESSON 4: INTRODUCTION TO PROGRAMMABLE CONTROLS

Evaluation Items:

1. Define programmable control.

2.1. List the five major parts of a programmable control.

a.

b.

c.

d.

e.

2.2. Explain what an input interface is and does.

2.3. Explain what an output interface is and does.

2.4. Explain what a CPU is and does.

2.5. Explain what a power supply is and does.

2.6. Explain what a programming device is and does.

3. List five reasons for using programmable control.

a.

b.

c.

d.

e.

4. List three uses of a programmable control on a hydraulic system.

a.

b.

c.

LESSON 4: INTRODUCTION TO PROGRAMMABLE CONTROLS

Answers to Evaluation Items:

1. A software based equivalent of a hardwired relay logic control.

2.1. a. Input interface
  b. Output interface
  c. CPU
  d. Power supply
  e. Programming device

2.2 -
2.6. Answers should contain information from text and/or lecture.

3. Reduced cost plus any other four from text.

4. a. Control a servo pump
  b. Proportional valve
  c. Proportional valve linked to "smart" cylinder